Draft
Interim Remedial Design
95 Percent Submittal

142nd Fighter Wing
Portland Air National Guard Base
Portland International Airport
Portland, Oregon

August 2002

ANG/CEVR
Andrews AFB, Maryland

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Prepared For:

Air National Guard
Installation Restoration Program
3500 Fetchet Avenue
Building R-47
Andrews AFB, Maryland 20762

Prepared By:

ERM®

Environmental Resources Management
915 118th Avenue S.E., Suite 130
Bellevue, Washington 98005

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LIST OF ACRONYMS/ABBREVIATIONS

Acronyms/ Abbreviations	Definitions
ANG	Air National Guard
ANGB	Air National Guard Base
bgs	Below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
C_2H_3Cl	Vinyl chloride
cis-1,2-DCE	cis-1,2-Dichloroethene
Cl^-	Chloride ion
CO_2	Carbon dioxide
COC	Contaminant of concern
DOE	United States Department of Energy
EE/CA	Engineering Evaluation/Cost Analysis
ERM	Environmental Resources Management
FS	Feasibility Study
H_2O	Water
HDPE	High density polyethylene
IRD	Interim remedial design
IRP	Installation Restoration Program
K^+	Potassium ion
$KMnO_4$	Potassium permanganate
mg/kg	Milligrams per kilogram
MNA	Monitored natural attenuation
MnO_2	Manganese dioxide
OH^-	Hydroxyl ion
ODEQ	Oregon Department of Environmental Quality
ORC	Oxygen Release Compound
OWS	Oil/water separator
pH	Acidity/alkalinity
PVC	Polyvinyl chloride
RAO	Remedial Action Objective
redox	Reduction-oxidation
RI	Remedial Investigation
SVE	Soil vapor extraction
µg/L	Micrograms per liter
USEPA	United States Environmental Protection Agency
VC	Vinyl chloride
VOC	Volatile organic compound

SECTION 1.0

INTRODUCTION

1.1 Purpose of Submittal

Environmental Resources Management (ERM) has prepared this *Interim Remedial Design 95 Percent Submittal* for a non-time-critical removal action to be conducted for groundwater at the 142nd Fighter Wing, Portland Air National Guard Base (Portland ANGB), Portland International Airport, Portland, Oregon. This removal action and interim remedial design (IRD) are being conducted as part of the Air National Guard (ANG) Installation Restoration Program (IRP), under contract DAHA90-94-0014/0101 between ERM and the National Guard Bureau.

This IRD focuses on an area of chemically impacted groundwater at the Portland ANGB within IRP Site 11 (Drawing C-1, Appendix A). Additionally, the IRD addresses limited residual soil contaminants at IRP Site 11 (Drawing C-5, Appendix A).

The removal action described in this document was selected as the preferred alternative based on the results of an Engineering Evaluation/Cost Analysis (EE/CA) for groundwater at IRP Site 11. Further information regarding the remedy identification and evaluation process can be found in the *Final Engineering Evaluation/Cost Analysis for Groundwater at IRP Site 11* (ERM, 2001c). A Feasibility Study (FS) for the entire Portland ANGB was completed in July 2001 (ERM, 2001d). The FS evaluates and recommends alternatives for the final remedies at the Portland ANGB IRP sites, including Site 11.

1.2 Site Evaluation

Between 1987 and 2000, four significant investigation activities were completed at the Portland ANGB: the Preliminary Assessment; the Site Investigation; the Remedial Investigation (RI); and the soil EE/CA investigation at Site 11. These investigations identified petroleum and chlorinated hydrocarbons above project screening goals in soil and groundwater. The results of these investigations are summarized in the

Final Remedial Investigation Report (ERM, 2001a). Figures 2-13 and 2-15 in the groundwater EE/CA (ERM, 2001c) present the extent of chlorinated hydrocarbons in Shallow Zone and Deep Zone groundwater, respectively.

An EE/CA and a removal action were performed for soils media at IRP Site 11 in September 1999 to remove impacted soil in the vicinity of the former oil/water separator (OWS). Confirmation samples collected from the soil excavation limits indicated residual contamination remained in the area of the former OWS. The removal action results are summarized in the *Final Completion Report for Site 11 Interim Remedial Action Construction for Soils Media* (ERM, 2000).

Based on the results of previous investigations, a baseline risk assessment, and the 1999 soil removal action, the following recommendations were developed for IRP Site 11 as part of the RI:

- Groundwater remediation is necessary to prevent possible off-site migration and residential use of impacted groundwater.

- Concentrations of volatile organic compounds (VOCs) (e.g., cis-1,2-dichloroethene [cis-1,2-DCE]) in soil remaining at the excavation limits of the 1999 soil removal action should be remediated to prevent potential migration of contaminants to groundwater.

To achieve these recommendations, a phased approach was developed for implementation of remedial actions at IRP Site 11. The first phase of treatment includes the application of a remediation technology within the area of highest contaminant concentrations to reduce these concentrations to acceptable levels, or to the extent technically practical. By reducing the highest concentrations of VOCs in Shallow Zone groundwater, favorable conditions will be created for subsequent natural attenuation of the remaining VOCs in groundwater. The limited residual soil contamination is also addressed during this phase. This first phase of treatment is considered an interim remedial action, the scope of which is addressed by the groundwater EE/CA (ERM, 2001c) and this IRD.

Following the completion of the first phase of treatment, conditions will be reassessed to evaluate the potential use of passive or additional active treatment technologies. Phase II treatment may include the application of one or several technologies to further reduce contaminant concentrations to acceptable levels across the site. Phase III treatment will address residual risk at the site and ensure adequate protection of human health and the environment. Phases II and III will constitute the final remedy for the site. The specific Phase II and III activities will be determined following selection of the final remedy and will be based on the results of the RI, baseline risk assessment, and FS.

1.3 Organization of Submittal

This document is organized into five sections and five appendices, as outlined below:

- Section 1.0 discusses the purpose and organization of the submittal; and summarizes site conditions and the IRD;
- Section 2.0 presents remedial action objectives (RAOs) and evaluates remedial alternatives, and presents the design basis for the selected removal action;
- Section 3.0 presents implementation details of the proposed removal action;
- Section 4.0 presents the project schedule;
- Section 5.0 lists references;
- Appendix A includes drawings detailing the 95 Percent IRD;
- Appendix B includes the construction design specifications;
- Appendix C includes the design calculations;
- Appendix D includes material safety data sheets; and
- Appendix E includes a Bid Form.

1.4 Summary of Interim Remedial Design

The discrete components of the selected removal action include:

- <u>Monitoring Well Installation</u> – The installation of additional Shallow Zone vertical monitoring wells within the active treatment area will monitor the effectiveness of the applied treatment.
- <u>Horizontal Injection Well Installation</u> – The installation of horizontal injection wells at the approximate vertical mid-point of the Shallow

Zone will address the area of highest VOC concentrations in groundwater.

- Potassium Permanganate Solution Injection – The injection of potassium permanganate solution into the area of highest VOC concentrations in groundwater will reduce concentrations by introducing an oxidant into the subsurface to oxidize the contaminants of concern (COCs).

- Groundwater Monitoring – Selected wells will be routinely monitored for monitored natural attenuation (MNA) parameters and COCs to monitor the potential for biodegradation, to ensure oxidants are being delivered throughout the Shallow Zone, and to confirm COC concentrations are decreasing.

- Soil Vapor Extraction System Installation – A soil vapor extraction (SVE) system will be installed and operated in the area of the former OWS to remove residual VOCs from soil in the unsaturated zone and to enhance bioremediation in the area.

- Soil Vapor Extraction System Operation and Maintenance – The SVE system will be routinely monitored and sampled to ensure biodegradation is occurring and COC concentrations are decreasing.

- Oxygen-Releasing Material Injection – To enhance bioremediation in the former OWS area, oxygen-releasing material will be injected into the saturated zone to reduce residual contaminants in the area.

SECTION 2.0

PROPOSED REMOVAL ACTION

This section summarizes the objectives of the interim remedial action, evaluates remedial alternatives, and presents a summary and design basis for the selected removal action. The RAOs were developed in detail in the EE/CA report (ERM, 2001c).

2.1 Identification of Remedial Action Objectives

The overall RAOs for IRP Site 11 were developed as part of the FS (ERM, 2001d) (and groundwater EE/CA report [ERM, 2001c]). The scope of the non-time-critical removal action for groundwater was developed as part of the groundwater EE/CA. The RAOs for the Portland ANGB correspond with exposure pathways and Federal and State requirements. The groundwater RAOs are as follows:

- Prevent off-site migration of groundwater containing VOCs above 10^{-6} risk concentrations for individual carcinogens;
- Treat groundwater to concentrations below Federal maximum contaminant levels; and
- Prevent on-site exposure to groundwater containing VOCs above 10^{-6} risk concentrations for individual carcinogens.

The soil RAO is as follows:

- Prevent dermal contact, or incidental ingestion, of soil containing VOCs above 10^{-6} risk concentrations for individual carcinogens.

All three groundwater RAOs may not be met during this interim remedial action. However, by removing the highest concentrations of VOCs, it is probable that the first RAO (prevention of off-site migration) will be met. The second and third RAOs will be achieved through the final remedy for the site and will be selected in accordance with Oregon Department of Environmental Quality (ODEQ) rules and regulations.

The interim soil remedial actions (SVE and oxygen-releasing material injection) included as part of this IRD are designed to meet the soil RAO for the site.

2.2 Evaluation of Remedial Alternatives

Six remedial alternatives were developed during the groundwater EE/CA for evaluation. A detailed individual analysis of each alternative was performed as part of the groundwater EE/CA to select the preferred alternative for IRP Site 11 (ERM, 2001c). The remedial alternatives considered for IRP Site 11 are summarized below.

- **Alternative 1 – No Action:** The EE/CA process requires consideration of the No Action alternative. Under this alternative, no site modifications or monitoring would be implemented to prevent or eliminate human health and environmental risks.

- **Alternative 2 – Monitored Natural Attenuation:** The use of MNA to achieve remedial objectives relies on biological, physical, and chemical processes occurring in the environment without artificial stimulus. Monitoring and documenting the intrinsic bioremediation element of natural attenuation is the major focus of this alternative. Under this alternative, active treatment measures would not be taken.

- **Alternative 3 – In Situ Oxidation - Potassium Permanganate Solution Injection:** This alternative was selected for the interim remedial action. The alternative is described in detail in Section 2.3.

- **Alternative 4 – In Situ Oxidation - Ozonation:** Ozonation involves the injection of a mixture of air and ozone gas at the bottom of the saturated zone within the area of highest VOC concentrations. Ozone is a strong oxidant known to rapidly destroy VOCs. This alternative also includes the use of MNA sampling to evaluate the potential to apply MNA in the final remedy for the site.

- **Alternative 5 – Enhanced Bioremediation:** Enhanced bioremediation involves the injection of a material that stimulates the natural biological activity in the area of highest VOC concentrations. This alternative also includes the use of MNA sampling to evaluate the potential to apply MNA in the final remedy for the site.

- **Alternative 6 – In-Well Aeration:** In-well aeration involves air-stripping of VOCs within a treatment well. Within each aerator well, water is pumped from a lower screen to the upper section of the well where it is sparged with injected air. The sparged water is then allowed to flow back into the soil through an upper well screen. This alternative also includes the use of MNA sampling to evaluate the potential to apply MNA in the final remedy for the site.

- **Former OWS Area Treatment – Common to Alternatives 2, 3, 4, 5, and 6:** This element includes installation of an SVE system and injection of oxygen-releasing material to remove VOCs and enhance bioremediation in saturated and unsaturated soils proximal to the former OWS. Treatment of the former OWS area would be implemented for each of Alternatives 2 through 6, and is therefore described separately.

2.3 Selected Removal Action

The remedial alternatives were evaluated in the *Final Engineering Evaluation/Cost Analysis Report for Groundwater at IRP Site 11* (ERM, 2001c) using the criteria set forth in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]* (United States Environmental Protection Agency [USEPA], 1988) and *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (USEPA, 1993).

Based on this evaluation, Alternative 3 was selected as the preferred alternative. Alternative 3 involves implementation of in situ oxidation using potassium permanganate injection as the primary treatment method. MNA sampling will be used to measure the potential for natural degradation of low concentration constituents immediately outside the active treatment area. The active treatment duration for this alternative is expected to be 1 year, followed by an additional year of monitoring. The 1-year treatment duration is an approximation based on the reduction of VOC concentrations observed during the in situ oxidation pilot tests conducted at IRP Site 2 (the geology, hydrology, and VOC concentrations at IRP Sites 2 and 11 are similar) and the results of similar in situ permanganate applications (ERM, 2001a). At the end of the 1-year treatment period, conditions will be reassessed based on the monitoring results, and it will be determined if additional applications of permanganate, or possibly additional injection wells, are required. The 1-year monitoring period following treatment is intended to monitor concentrations for a short period after the active treatment period.

Alternative 3 will be implemented as follows:

- Install four Shallow Zone monitoring wells within and surrounding the active treatment area.

- Initially install four Shallow Zone horizontal injection wells to address the area impacted by approximately 100 micrograms per liter (μg/L) of combined cis-1,2-DCE and vinyl chloride (VC). These wells will be placed at the approximate vertical mid-point of the Shallow Zone (approximately 21 feet below ground surface [bgs]) and perforated across the 100-μg/L area. This injection depth will allow influence of the entire vertical extent of the Shallow Zone. Horizontal injection wells were selected over vertical wells or direct-push drilling methods to prevent disturbance of flight operations or the concrete flight apron.

- Perform a laboratory treatability test to determine the native soil demand for potassium permanganate with soil and water collected during the monitoring well installation.

- Perform injection pilot test. Inject potassium permanganate as a 2 percent, water-based solution in the southernmost injection well (Well D, Drawing C-2). Monitor water levels and collect colorometric samples from adjacent monitoring wells to determine the effect of the injection volume.

- Inject potassium permanganate as a 2 percent, water-based solution in each injection well. Approximately 45,000 total gallons of permanganate solution will be injected into the treatment area per application. This volume is based on the constituent stoichiometric demand and the estimated native soil demand including a safety factor of 2 (Appendix C). The actual volume may change pending the results of the treatability test and the pilot test performed during monitoring and injection well installations. These injections will initially be performed every 6 months for 1 year, resulting in a total of two applications.

- For planning and budgeting purposes, the new and existing wells will be monitored quarterly for 2 years (1 year during active treatment, 1 year post-treatment). The long-term monitoring program will depend on the selection of the final remedy and the effectiveness of the interim remedial action. Thirteen Shallow Zone wells will be monitored for VOC concentrations, select metals, and MNA parameters.

This alternative also includes treatment of the former OWS area. To achieve the soil RAO identified in Section 2.1, an SVE system will be installed and operated in the area of the former OWS to remove residual VOCs from the soil and enhance bioremediation in the area.

The SVE system at IRP Site 11 will be implemented as follows:

- Install vapor monitoring points using direct-push drilling methods to evaluate the effective radius of influence of the system, as well as concentrations of VOCs and other parameters in soil.

- Install SVE equipment.

- Connect SVE equipment to the existing piping.

- For planning and budgeting purposes, the SVE system will be operated for 2 years, including monthly visits for system monitoring, operation, and maintenance. The long-term monitoring program will be dependent on the selection of the final remedy and the effectiveness of the interim removal action.

Treatment of the former OWS area will also include several injections of oxygen-releasing material in the saturated zone using direct-push drilling methods. Injections will be performed during high water table conditions to treat areas of residual contaminants outside and below the excavation limits of the 1999 soil removal action.

Alternative 3 was selected because it best satisfies the protectiveness criterion and remedy-selection balancing factors. Alternative 3 is one of the most protective alternatives based on its ability to achieve the site RAOs within a reasonable time period. The costs for this alternative are significantly less than the other two alternatives that meet the protectiveness criterion (i.e., Alternatives 4 and 6).

Alternatives 5 and 6 are most likely not implementable due to the large number of corings and trenching required in the thick concrete, which would jeopardize the integrity of the flight apron. Additionally, the interruption of flight operations required to perform these alternatives is unacceptable.

Because Alternatives 3 and 4 can be implemented using directionally drilled horizontal wells, the impacted area below the flight apron can be treated without adversely impacting flight operations. Based on these construction and installation issues, Alternatives 3 and 4 are more implementable.

Alternative 3 has been proven effective at the Portland ANGB during the Phase I Interim Remedial Action Construction (ERM, 2001b), and the technology is likely to be successful at significantly reducing the highest concentrations of VOCs at IRP Site 11. Additionally, this alternative is much less expensive than Alternative 4.

By implementing Alternative 3, the following is expected to be achieved:

- Destruction of the majority of VOC mass in groundwater at IRP Site 11 (source reduction);
- Prevention of further vertical migration of VOCs to the Deep Zone;
- Prevention of lateral migration of high-concentration VOCs to outer areas of the Shallow Zone; and
- Promotion of natural attenuation of VOCs in the Deep Zone and outer areas of the Shallow Zone through reduced source-area concentrations.

2.4 Basis of Design

This section presents the general basis of design for several design elements presented in this document.

2.4.1 Groundwater Monitoring Wells

The groundwater monitoring wells will be installed similar to previous monitoring wells installed at the site. The following paragraphs provide the basis of design for the well screen slot size and filter pack.

Monitoring wells will be constructed in accordance with State of Oregon well construction standards and guidance contained in *Groundwater Monitoring Well Drilling, Construction, and Decommissioning* (ODEQ, 1992). The wells will be constructed of 2-inch diameter, flush-threaded, Schedule 40 polyvinyl chloride (PVC) casing with machine-slotted screen. The well screen will have a slot width of 0.010 inches; this slot width was selected based on the filter pack to be used (see below) and site stratigraphy. The selected slot width is capable of retaining at least 90 percent of the filter pack material. Screened intervals are expected to be predominately in fine to medium sand water-bearing formations.

A sand filter pack will be installed in each well by filling the annular space between the well screen and the borehole wall with clean, well-sorted, silica sand to approximately 1 to 3 feet above the top of the well screen. This filter pack material was selected such that it will: (1) minimize the amount of fine-grained sediment entering the well; (2) allow for proper well development; (3) not inhibit the inflow of groundwater to the well; and (4) not affect the chemistry of water samples collected from the well.

A bentonite filter pack seal at least 2 feet thick will be installed above the sand filter pack. The remaining annular space above the bentonite seal will be filled with concrete.

2.4.2 Horizontal Injection Wells

The preferred method for injecting potassium permanganate is typically through closely spaced, vertical, direct-push injection locations. However, direct-push injection is not implementable at this site due to the location of the treatment area under an active flight apron. The use of direct-push injection would require significant coring of the thick flight apron concrete and interruption of flight activities. Based on the requirements of the ANGB, this is not acceptable. Due to these constraints, the use of directionally drilled horizontal wells is required.

The locations of the four proposed horizontal injection wells are shown on Figure C-2 in Appendix A. The orientation of the injection wells was designed based on construction constraints presented by the active flight apron. A north-south well orientation would interfere with flight operations in the northern area of IRP Site 11. Disturbance of the flight apron concrete in the areas of the well entrances and exits would also be unacceptable.

Directionally drilled horizontal wells will allow access to the subsurface below buildings, utilities, and the flight apron. The drilling method proposed for this IRD will allow directional control during installation of the well borehole, thereby allowing circumvention of subsurface and surface obstructions.

Installation of the horizontal injection wells is not expected to affect the integrity of the flight apron. The majority of the boreholes will be drilled at 21 feet bgs. At this depth, drilling is expected to have no effect on the flight apron. Even in the areas where the borehole is shallow (the entrance and the exit), the diameter of the borehole will be small enough to not have any effect. Also, to control drilling fluids, well installation will require cutting and removal of a 6-foot by 2-foot section of concrete at the well entrance. The area will then be excavated to 4 feet bgs. However, none of the well entrance or exit locations are planned within the area of active flight operations.

The target depth for the horizontal well injection interval is 21 feet bgs, the approximate middle of the Shallow Zone. Borehole logs from monitoring wells MW11-1, MW11-3, MW11-4, MW11-5, and MW11-6 (ERM, 2001a) within the treatment area indicate the Shallow Zone is between 16 and 26 feet bgs. The Shallow Zone has historically contained the highest VOC concentrations.

The relatively small thickness of soil between the top of the Shallow Zone (approximately 16 feet bgs) and the injection well (21 feet bgs) will be addressed through the mixing of groundwater and permanganate as a result of pressurized injection. The amount of impacted soil in the Floodplain Silts above 16 feet bgs is expected to be minimal due to the low hydraulic conductivity and low porosity of this formation.

The horizontal injection wells will be continuously drilled using biodegradable, clay-free drilling fluid. The drilling fluid will be broken down chemically by injecting a concentrated powdered enzyme into the well. Material safety data sheets for one possible drilling fluid and break-down chemical option are included in Appendix D.

The well construction material for the injection wells will be high-density polyethylene (HDPE). According to the Plastic Pipe Institute's Chemical Resistance Chart, HDPE is compatible with potassium permanganate at temperatures up to 140 degrees Fahrenheit and concentrations up to 25 percent. Since the anticipated temperatures and permanganate concentrations to be used in the interim action are much less than this, no compatibility problems are expected.

The well material will be pulled through the open borehole. To prevent damage caused by the tensile stress applied to the HDPE material during well installation, the well material may be placed in a carrier casing. This carrier casing will also protect the perforated interval during installation and provide a conduit for well development fluids. Because the pipe is protected, there is less chance that the perforated interval will be smeared with drilling fluid, so the well development process is less time-consuming and less expensive. The perforated interval will also be wrapped in filter fabric to keep silt from entering the well once the pressure caused by development and injection is removed.

To obtain uniform distribution of potassium permanganate throughout the treatment area, the pressure drop across the well open area must be much greater than the pressure drop along the length of the perforated interval. (Perry and Green, 1997). To achieve this, 1/8-inch holes will be drilled into the HDPE pipe at 15-foot intervals (Appendix C). Additionally, at each location, the well will consist of a cluster of three pipes of different lengths, the total injection length comprising the sum of the three perforated intervals. This will allow for future injections in certain portions of the impacted area.

Phase I of treatment places four evenly spaced injection wells across the treatment area, resulting in an effective spacing of approximately 75 feet between each well. This spacing was not designed based on an expected radius of influence, but rather the number of injection wells was designed to allow phased application of the selected remedial alternative while evaluating its effectiveness. Due to expected local variations in groundwater flow direction and velocity, hydraulic conductivity, and localized flow pathways, it is difficult to accurately estimate the area of influence of the horizontal injections. Thus, a preliminary spacing of 75 feet was selected.

The area of influence will be evaluated through groundwater sampling during and after the permanganate applications. If the treatment is determined to be successful at reducing concentrations in the affected area, yet the desired area of influence is not achieved (i.e., if VOC concentrations are not reduced across the entire Shallow Zone treatment area), the possibility of additional injection wells or applications will be evaluated.

2.4.3 Injection Protocol

The goal of this removal action is to present a plan for delivering the oxidant (i.e., potassium permanganate) into the treatment area. An appropriate amount of permanganate solution must be injected into the subsurface to effectively treat the COCs.

The main COCs at IRP Site 11 are VC and cis-1,2-DCE. VC was used as a conservative, representative chemical to calculate the chemical stoichiometric demand of potassium permanganate because it possesses the highest oxidant demand of chlorinated ethenes. The reaction of permanganate with VC is represented in the following balanced stoichiometric equation:

$$10KMnO_4 + 3C_2H_3Cl \dashrightarrow 6CO_2 + 10MnO_2 + 10K^+ + 3Cl^- + 7OH^- + H_2O$$

Based on the above balanced equation, the mass of potassium permanganate required under ideal conditions to achieve a complete reaction is approximately 8.5 times that of VC (see calculations in Appendix C). A concentration of VC of 500 μg/L was selected for design purposes based on the maximum concentration of VC observed during previous groundwater sampling events at MW11-6.

Based on the assumed VC concentration of 500 milligrams per liter, the stoichiometric ratio of potassium permanganate mass to that of the VC, and an assumed effective porosity of 0.25, approximately 6.63E-05 pounds (1E-5 = 0.00001) of potassium permanganate must be injected per cubic foot of saturated soil to be treated (Appendix C). Considering that the target treatment zone for each well is approximately 75 feet wide and 10 feet thick, each foot of injection well screen must treat a volume of approximately 750 cubic feet. Using the mass of potassium permanganate required (6.63E-05 pounds) for each cubic foot of treatment area, approximately 0.05 pounds of potassium permanganate must be distributed across the treatment area for each foot of injection well screen.

In addition to the constituent stoichiometric demand for potassium permanganate, the soil demand must also be taken into account. The soil demand has not been determined for IRP Site 11. Based on an assumed organic carbon content in the soil of 0.1 percent, an assumed 5 percent destruction of native organic matter, and a one-to-one ratio of potassium permanganate usage to pound of organic material destroyed, approximately 2.45 pounds of potassium permanganate must be injected per foot of well screen to meet the soil demand (Appendix C).

Based on the constituent stoichiometric demand and the assumed soil demand for potassium permanganate, the potassium permanganate application rate is 2.5 pounds per foot of injection well. To promote lateral distribution, the potassium permanganate will be injected in the form of a dilute solution. The solution injected will be no stronger than 2 percent, by weight, potassium permanganate. A large volume of a dilute concentration solution is anticipated to result in a larger radius of influence during the injections (compared with a higher concentration solution delivering equal mass of permanganate). Based on the calculated 2.5 pounds of potassium permanganate per foot of well screen, a 2 percent solution, approximately 1,500 feet of total screen, and a safety factor of 2, the potassium permanganate solution volume prescribed in this IRD is 45,000 gallons per application to the treatment area.

The potassium permanganate injection volume will be adjusted as necessary during the removal action based on the results of the treatability test and the injection pilot test. The injection concentration will not change. During monitoring well installation, a bulk soil and a bulk groundwater sample will be collected to perform a laboratory treatability test with potassium permanganate. The treatability test results will be used to quantify the native soil demand for potassium permanganate. The soil demand will then be used to help redefine the injection volume.

The injection volume will be further defined by a field pilot test. The volume of potassium permanganate redefined by the pilot test will be injected into the first completed injection well while the others are being installed. The southernmost well (Well D) will be installed first due to its proximity to several monitoring wells, enhancing the amount of monitoring data available from this test. During the injection, water levels and colorometric samples will be collected at the four adjacent monitoring wells to determine the effects of the injection. Based on the field pilot test results, the injection volume may be redefined for the remainder of the wells.

To further ensure potassium permanganate is distributed over the maximum area within the treatment zone, a second injection will be applied 6 months following the initial injection. The second injection will likely be performed using the same volume of potassium permanganate, solution, and the same injection procedures, as the initial injection. As discussed in Section 2.4.2, if it is determined that the desired area of influence has not been achieved following completion of the first phase of treatment, additional injection applications may be performed.

2.4.4 Impacts to Groundwater Quality

Groundwater quality is not expected to be adversely impacted at the Portland ANGB as a result of this removal action. Potential impacts and mitigating factors are discussed below.

Potassium permanganate reacts rapidly with the double bonds in chlorinated ethenes. Permanganate oxidizes the chlorinated ethenes to carbon dioxide (CO_2) and chloride ion. The end products of the reaction of potassium permanganate with chlorinated VOCs are CO_2, water, hydroxide ion, potassium ion, manganese dioxide, and chloride ion. These end products are not expected to cause a detrimental impact to groundwater quality.

When the permanganate is reduced upon reaction with organic matter, it forms manganese dioxide, which is an insoluble brown precipitate under most conditions. However, precipitated manganese dioxide is not expected to inhibit groundwater flow at the low concentration of potassium permanganate that will be injected.

Unreacted permanganate can discolor groundwater (purple color). However, unreacted permanganate is not expected to reach a receptor, because the natural oxidant demand of native materials in the soil and groundwater will cause the permanganate to react with these materials before the permanganate can migrate a significant distance. This behavior was confirmed during the Phase I Interim Remedial Action Construction (ERM, 2001b), where purple-colored groundwater was not observed at a significant distance downgradient.

The altered oxidation state of the subsurface as a result of injected oxidant can cause the migration of metals (such as hexavalent chromium) that are more soluble, and potentially more toxic, in their oxidized state. Dissolved chromium was not detected in groundwater samples collected at IRP Site 11 during the RI and the highest chromium concentration detected in soil was 31 milligrams per kilogram (mg/kg), which is well below regulatory limits. Due to an induced oxidative state and slightly increased acidity/alkalinity (pH) resulting from the presence of potassium permanganate in groundwater, some chromium may oxidize to the hexavalent form and become mobile. However, this transformation is highly dependent on the pH and reduction-oxidation (redox) potential of the groundwater (Zumdahl, 1989). As groundwater flows away from the area immediately surrounding the injection location, or as the permanganate is used through oxidation, pH and redox values will decrease until they reach initial conditions. As pH and redox values equilibrate, the concentration of any mobilized hexavalent chromium will decrease correspondingly.

The raw material used for this technology is technical-grade, powdered potassium permanganate. This is the same material used in drinking water and wastewater treatment, and its composition is regulated by the American Water Works Association. It is possible that the material used could contain trace amounts of impurities from the manufacturing process. These impurities could include heavy metals such as chromium and mercury at very low concentrations. One manufacturer of potassium permanganate lists typical values of the three regulated impurities as less than 5 mg/kg cadmium, less than 20 mg/kg chromium, and less than 0.5 mg/kg mercury. At the concentration of potassium permanganate to be injected into the groundwater at IRP Site 11, the resulting concentrations of these three metals will be less than their respective

Federal Maximum Contaminant Levels. As the injectate disperses and mixes with groundwater immediately surrounding the injection location, the resulting concentrations will decrease further.

For verification, as part of the IRP Site 2 Interim Remedial Action Construction, a sample of 2 percent permanganate solution was analyzed for 12 metals (silver, arsenic, beryllium, cadmium, chromium, copper, nickel, lead, antimony, selenium, thallium, and zinc) by Trace Inductively Coupled Plasma Method (SW846 6010B) and for mercury by Manual Cold-Vapor Method (SW846 7470). The laboratory results indicated the only metal detected was chromium (0.1 milligrams per liter). This concentration is below the Federal Maximum Contaminant Level. However, for conservatism, chromium will be monitored during the groundwater sampling events as part of this removal action.

The long-term effects of potassium permanganate injection are expected to be favorable for subsequent natural attenuation of low concentrations of the remaining chlorinated VOCs in groundwater. Although the oxidative environment caused by the injected potassium permanganate may temporarily inhibit intrinsic biodegradation in the treatment area, intrinsic biological activity is expected to resume at pre-treatment levels soon after this oxidative environment attenuates.

The United States Department of Energy (DOE) evaluated the use of potassium permanganate in an Innovative Technology Summary Report titled *In Situ Chemical Oxidation using Potassium Permanganate* (DOE, 1999). The DOE made several conclusions regarding the use of potassium permanganate and associated community and regulatory issues. Among the conclusions of the DOE evaluation were the following:

- The materials injected (potassium permanganate) pose no hazard to the community or environment due to their low concentration after dispersal into the soil or groundwater.

- The community is not exposed to harmful by-products and there is no significant environmental impact as the overall reaction results in generation of CO_2, magnesium oxide solids, cations (e.g., potassium), and halides (when chlorinated solvents are present).

- In situ chemical oxidation using potassium permanganate does not produce VOCs (due to cleavage of the organic compound).

- No unusual or significant safety concerns are associated with transport of equipment or other materials associated with this technology.

2.4.5 Soil Vapor Extraction System

The use of SVE technology was selected for the area of residual soil contaminants near the former OWS during the 1999 soil removal action (ERM, 2000). SVE reduces contaminant concentrations in the subsurface through two mechanisms: 1) direct removal (mass transfer) of volatile compounds; and 2) enhanced bioremediation.

The first mechanism (direct removal) is achieved through creation of increased air flow in the subsurface using a vacuum blower, which promotes volatilization of COCs from the soil. The vapor stream is then processed through a vapor treatment system to remove the volatilized COCs.

The second mechanism (enhanced bioremediation) is achieved through increased oxygen concentration in the subsurface created by the induced air flow from vapor extraction. Intrinsic microorganisms use oxygen to break down organic chemicals (e.g., petroleum hydrocarbons) in soil. By increasing the amount of available oxygen, the intrinsic bioactivity in soils is typically increased, thereby reducing the COC mass over time. The amount of biodegraded contaminant mass can be estimated by monitoring CO_2 concentrations in the vapor extraction effluent stream, as well as at vapor monitoring points. The amount of COCs destroyed through enhanced bioremediation is often larger than the mass removed via volatilization.

SVE piping was installed in the former OWS area during the 1999 soil removal action. This piping will be used during the groundwater removal action. Due to the limited extent of the existing piping, the higher porosity of the fill material, and the small thickness of the vadose zone, the SVE system is expected to have a limited impact within the treatment area, primarily within the area of the 1999 soil removal excavation. To address residual contaminants outside of the excavation limits and within the saturated zone proximal to the former OWS, oxygen-releasing material will be injected into these areas. Oxygen-releasing material injection is described below.

2.4.6 Oxygen-Releasing Material Injection

In situ biological treatment involves injection of a material that stimulates the natural biological activity of the impacted zone, which can become depressed after an extended period of contaminant degradation. Some sites are capable of extensive contaminant removal if depleted growth factors are replenished. Biological activity in an impacted zone is frequently limited by the availability of a single growth factor, such as an electron acceptor or donor. Supplying this growth factor can often stimulate bacterial growth and biodegradation of COCs. This treatment approach is generally used to reduce saturated zone COC concentrations.

Enhanced aerobic bioremediation involves injecting the material used to stimulate biological activity into the impacted zone. Depending on the material used and the concentration of contaminants being treated, the material may require multiple injections to maintain optimal conditions.

In cases where aerobic respiration is the preferred biological pathway for constituent degradation, oxygen acts as the electron acceptor and is frequently depleted. The petroleum and chlorinated hydrocarbons within the former OWS area are capable of degrading by aerobic bioremediation. A lack of oxygen results in the use of other electron acceptors and biological pathways, which are much slower than aerobic respiration. Increasing the dissolved oxygen content in the impacted zone ensures that aerobic respiration is the dominant biological pathway. This can be accomplished by injecting a substance that slowly releases oxygen.

One material that has been shown to be effective at treating a variety of contaminants is Oxygen Release Compound (ORC), produced by REGENESIS Bioremediation Products. ORC is a magnesium peroxide-containing material that slowly releases elemental oxygen when hydrated.

ORC has been demonstrated to be very successful at promoting aerobic degradation of benzene, toluene, ethylbenzene, xylene, chlorobenzene, dichlorobenzene and VC, as well as reducing concentrations of total petroleum hydrocarbons. These are the primary residual contaminants in soil that exceed project screening goals in the former OWS area.

ORC has not been proven effective in remediating tetrachloroethene and trichloroethene. Only one detection of tetrachloroethene was observed in the former OWS area (0.07 mg/kg in Sample GP11-6, collected at 5 feet bgs). This is below the Oregon Soil Cleanup Level of 0.3 mg/kg. No detections of trichloroethene above the project screening goals were observed in the former OWS area in soil confirmation samples collected after the 1999 soil removal action.

A pilot test using ORC was conducted at IRP Site 2 (ERM, 2001b). The purpose of the test was to evaluate the effectiveness of ORC at reducing chlorinated VOCs in Shallow Zone groundwater and to determine a radius of influence for the injected ORC. Significant reduction of chlorinated VOC concentrations in groundwater was observed, particularly cis-1,2-DCE and VC. Over the 3-month test duration, VC, cis-1,2-DCE, and trans-1,2-dichloroethene were reduced by 70 to 75 percent at the furthest downgradient monitoring well, 12 feet from the injection location. Because the biological treatment of VOCs is slower than other methods, it can be assumed that the radius of influence for this test is at least 12 feet. Further details regarding the results of the pilot test are presented in *Interim Remedial Action Construction - Phase 1 Interim Report* (ERM, 2001b).

As part of this removal action, ORC will be injected into the saturated zone outside and below the 1999 soil removal excavation limits. The focus will be the areas proximal to the former OWS where SVE is not expected to be effective at removing residual contaminants.

SECTION 3.0

REMEDIAL ACTION IMPLEMENTATION

This section provides a summary of existing conditions and the plans for implementing the groundwater removal action at IRP Site 11.

3.1 Existing Conditions

IRP Site 11 was identified as an area of environmental concern following ANG IRP site investigations conducted between 1995 and 2000. Two sources of contamination were identified at IRP Site 11: the former OWS, and residual contaminants in the subgrade material beneath the flight apron and former washrack. Contamination at Site 11 was determined to pose a potential risk to human health. Detailed discussions of the site investigations, existing site conditions, and associated health risks are included in the Portland ANGB *Final Remedial Investigation Report* (ERM, 2001a). An existing site plan is included as Drawing C-1 (Appendix A).

3.2 Monitoring Well Installation

Four groundwater monitoring wells will be installed in the Shallow Zone to further define the extent of COCs in groundwater and to monitor the effectiveness of oxidant injection at IRP Site 11. The monitoring wells will be constructed and monitored similar to those installed during the RI to allow for collection of comparable groundwater quality data. The basis of design for the well screen slot size and filter pack is provided in Section 2.4.1. The proposed monitoring well locations are shown on Drawing C-2 (Appendix A). The monitoring well construction details are shown on Drawing C-4 (Appendix A) and outlined in Section 02000 of Appendix B. During monitoring well installation, bulk groundwater and bulk soil samples will be collected for the laboratory treatability test to determine soil oxidant demand and concentrations of VOCs. These results will be taken into account in the final determination of the horizontal injection well locations and injection volumes.

3.3 Injection Well Installation

Initially, four directionally drilled horizontal injection well clusters will be installed within the Shallow Zone treatment area, as shown on Drawing C-2 (Appendix A). Each well cluster will consist of three separate injection wells screened over different intervals, to ensure uniform permanganate distribution and to allow targeted injection into specific zones within the treatment area. The wells will be installed approximately 75 feet apart at an approximate depth of 21 feet bgs. As discussed in Section 2.4.2, additional injection wells may be installed following completion of the first phase of treatment, based on the monitoring results. The horizontal well construction details are shown on Drawings C-3 and C-4 (Appendix A) and specified in Section 02100 (Appendix B).

3.4 Potassium Permanganate Solution Injection

Based on the rationale presented in Section 2.4.3, potassium permanganate solution will be injected as a 2 percent, water-based solution in each injection well. Approximately 45,000 gallons of permanganate solution will be injected into the treatment area per application. This injection volume is derived from the constituent stoichiometric demand and the assumed native soil demand, and will be adjusted as necessary based on the laboratory treatability test and the injection pilot test. The treatability test will be performed during monitoring well installation and the injection pilot test will be performed after installation of the first injection well. The potassium permanganate solution injection procedures are specified in Section 02200 of Appendix B.

3.5 Groundwater Monitoring

Groundwater sampling will be performed quarterly for 2 years. Prior to potassium permanganate injection, initial baseline samples will be collected to obtain data on redox potential, concentrations of metals, dissolved oxygen, chloride ions, and concentrations of VOCs. Following the potassium permanganate injection, sampling will be performed to monitor for COCs and MNA parameters in groundwater. Groundwater samples will be collected from the six new monitoring wells, as well as the seven existing Shallow Zone monitoring wells (MW11-1, MW11-3, MW11-4, MW11-5, MW11-6, MW11-10, and MW11-13). The groundwater samples will be analyzed for the following parameters:

- Field parameters, including redox potential, dissolved oxygen, specific conductance, temperature, pH, and turbidity;
- Chlorinated VOCs using USEPA Method 8260B;
- Dissolved chromium, cadmium, iron, manganese, and potassium using USEPA Method 6010B;
- Dissolved mercury using USEPA Method 7470A; and
- Chloride ion using USEPA Method 300.0.

Depending on the groundwater monitoring results, the sampling frequency may be modified, as appropriate. The groundwater monitoring procedures and analyses are specified in Section 02300 of Appendix B.

3.6 Soil Vapor Extraction System Installation

To remove residual VOCs from soil and enhance bioremediation in the area, an SVE system will be installed in the area of the former OWS, as shown on Drawing C-5 (Appendix A). A process flow and piping and instrumentation diagram for the SVE system is presented on Drawing C-6 (Appendix A). Drawing C-7 (Appendix A) presents the SVE system details. The SVE system installation details are outlined in Section 02400 of Appendix B.

The SVE system will be connected to existing piping installed during the 1999 soil removal action. The existing piping consists of two horizontal, 4-inch-diameter, Schedule 40 PVC pipes installed at approximately 5 feet bgs within the excavation fill material. Both pipes have alternating blank casing and screen lengths of 20 feet.

A horizontal, 1-inch-diameter, Schedule 80 PVC pipe with drilled perforations was also installed during the 1999 soil removal action for possible future injection of liquids to enhance bioremediation or oxidize residual contaminants (ERM, 2000). This injection pipe may be used in the future for injection of potassium permanganate, sodium persulfate (effective for treating aromatic VOCs such as benzene), or oxygen-releasing material.

3.7 Soil Vapor Extraction System Operation and Maintenance

It is expected that the SVE system will be operated for 2 years. SVE system operation and effluent monitoring data will be used to evaluate the effectiveness of the system. Monitoring and maintenance of the system will be performed monthly. Details of SVE system operation and maintenance activities are presented in Section 02500 of Appendix B.

3.8 Oxygen-Releasing Material Injection

Treatment of the former OWS area will include 12 injections of oxygen-releasing material in the saturated zone using direct-push drilling methods. Injections will be performed during high water table conditions to maximize the thickness of the treatment area. Injections will target the areas outside and below the excavation limits of the 1999 soil removal action, based on the 1999 confirmation sample results (ERM, 2000). Injection procedures are discussed in Section 02600 of Appendix B.

SECTION 4.0

PROJECT SCHEDULE

The anticipated project schedule for removal action implementation is discussed below. Specific dates of implementation will depend upon the date of contractor selection.

Following award of the remediation contract, the contractor will complete and submit the appropriate State underground injection control forms. Based on previous in situ chemical oxidation injections at the Portland ANGB, it is anticipated that the ANG will not be required to obtain permits for the injection program (ODEQ, 2000). However, per the substantive permit requirements, the EE/CA Report (ERM, 2001c) and Action Memorandum will be made available for public comment. The ANG will provide public notice and a 30-day opportunity to comment on the proposed injection activities.

Preparation for field activities will begin at the end of the 30-day comment period, if no public meeting is required. During preparation for field activities, the contractor will obtain Start Cards for the groundwater monitoring wells and perform a utility locate. It is anticipated that work will begin 2 weeks following the end of the public comment period.

It is anticipated that initial field activities will require approximately 4 months to complete. This will include groundwater monitoring well installation, development, and sampling; horizontal injection well installation and development; laboratory treatability and field pilot testing; one potassium permanganate injection application at four wells; SVE system installation and startup; and oxygen-releasing material injection. The second application of potassium permanganate (i.e., 6 months after the first application) will require approximately 2 weeks of field work.

Characterization and disposal of investigation-derived waste (e.g., drill cuttings, well development, and purge water) is expected to require approximately 1 month. Quarterly groundwater monitoring and monthly SVE system operation and maintenance will be performed for 2 years following the initial permanganate application.

SECTION 5.0

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APPENDIX A

95 PERCENT DESIGN DRAWINGS

142nd FIGHTER WING

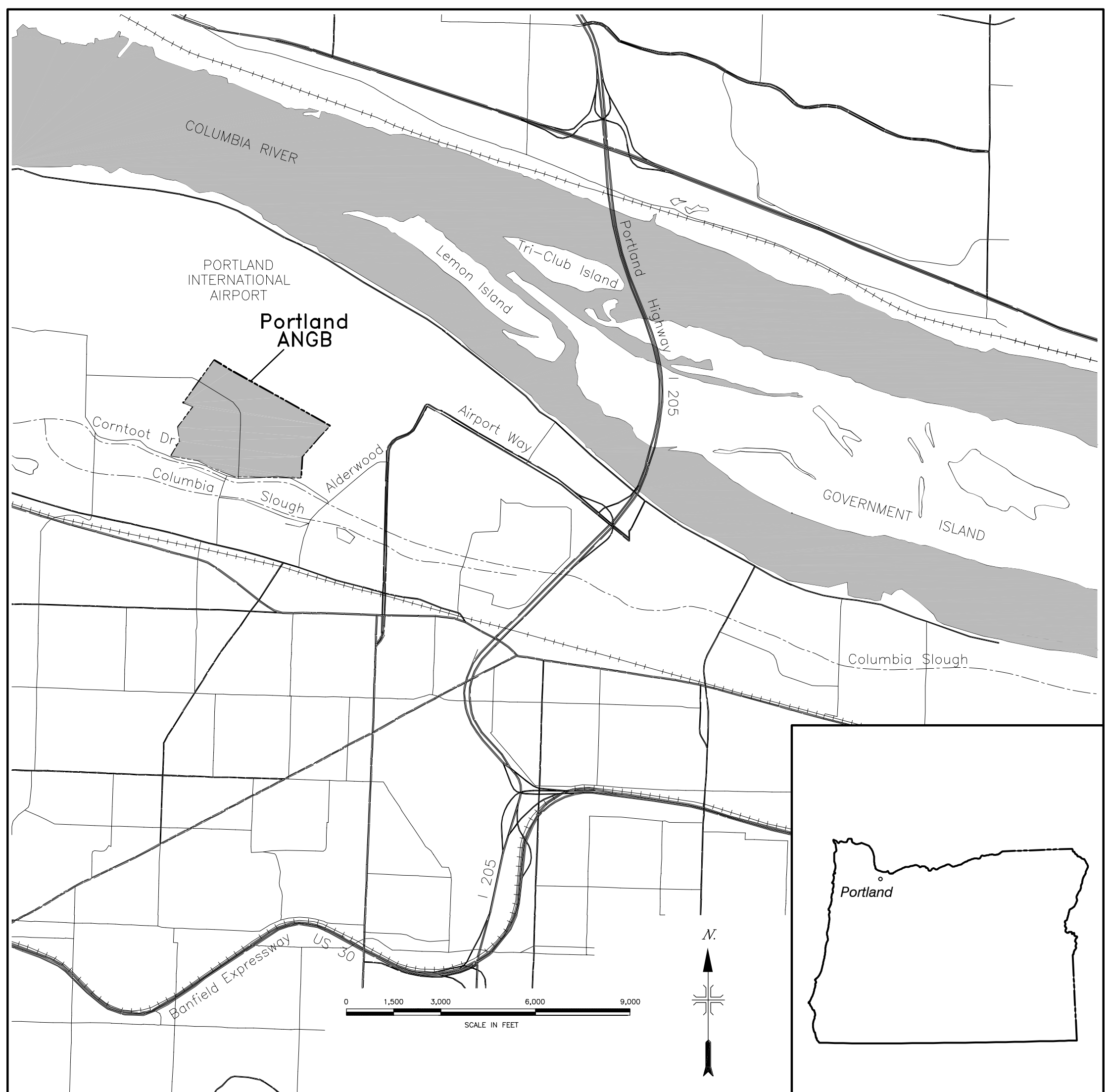
PORTLAND AIR NATIONAL GUARD

PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON

INTERIM REMEDIAL DESIGN 95 PERCENT SUBMITTAL

IN SITU TREATMENT OF IMPACTED GROUNDWATER AND SOIL AT IRP SITE NO. 11

AUGUST 2001



LOCATION MAP

INDEX OF DRAWINGS

DRAWING NO.	DISC. NO.	DESCRIPTION
D-6101.52-01	T-1	LOCATION MAP, INDEX OF DRAWINGS
D-6101.52-02	T-2	GENERAL NOTES, LEGEND & ABBREVIATIONS
D-6101.52-03	C-1	EXISTING SITE PLAN
D-6101.52-04	C-2	PERMANGANATE INJECTION SYSTEM PLAN
D-6101.52-05	C-3	HORIZONTAL INJECTION WELL TYPICAL CROSS SECTION
D-6101.52-07	C-4	WELL CONSTRUCTION DETAILS
D-6101.52-06	C-5	SVE SYSTEM PLAN
D-6101.52-08	C-6	SVE SYSTEM PROCESS FLOW PIPING AND INSTRUMENATION DIAGRAM
D-6101.52-09	C-7	SVE SYSTEM DETAILS
D-6101.52-10	C-8	UTILITIES MAP

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LOCATION MAP, INDEX OF DRAWINGS

SCALE	DESIGNED BY	DRAWN BY	DRAWING NUMBER
AS NOTED	H. LEE	J. ESTRADA	D-6101.52.01
DATE	CHECKED	APPROVED	JOB NUMBER
10/09/01	E. IPSEN	A. CHEMBURKAR, PE	6101.52

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SHEET 1 of

PORTLAND AIR NATIONAL GUARD
PORTLAND, OREGON

DISCIPLINE NO. T-1

ENVIRONMENTAL RESOURCES MANAGEMENT

CONSTRUCTION NOTES

GENERAL

1. ALL WORK SHALL BE PERFORMED AND COMPLETED IN ACCORDANCE WITH ALL FEDERAL, STATE, AND LOCAL CODES.

2. CONTRACTOR SHALL BE RESPONSIBLE FOR VERIFYING ALL FIELD DIMENSIONS BEFORE BEGINNING WORK. ANY CONFLICTS WITH DRAWINGS SHALL BE NOTED AT THAT TIME.

3. THIS SITE IS KNOWN TO HAVE HAZARDOUS MATERIALS. HAZARDOUS MATERIALS MAY BE ENCOUNTERED DURING THIS WORK. THE CONTRACTOR SHALL ADHERE TO A SITE-SPECIFIC HEALTH AND SAFETY PLAN IN ACCORDANCE WITH U.S. DEPARTMENT OF LABOR, 29 CFR 1910.120 AND STATE OSHA REQUIREMENTS FOR WORKING AT HAZARDOUS MATERIALS SITE. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE TRAINING AND SAFETY OF HIS EMPLOYEES. IN THE EVENT THAT HAZARDOUS MATERIALS ARE ENCOUNTERED, THE BASE CIVIL ENGINEER AND CONTRACTING OFFICER'S REPRESENTATIVE SHALL BE NOTIFIED IMMEDIATELY.

TRENCHING, EXCAVATION AND BACKFILL

4. ALL TRENCHES AND EXCAVATIONS SHALL COMPLY WITH OSHA REGULATIONS AND THE OSHA GUIDE FOR THE CONSTRUCTION INDUSTRY.

5. PRIOR TO COMMENCEMENT OF WORK, CONTRACTOR SHALL COORDINATE WITH BASE CIVIL ENGINEER TO MARK PROPOSED LOCATION OF EXCAVATION WORK TO MINIMIZE INTERFERENCE WITH EXISTING UTILITIES. IN ADDITION, CONTRACTOR SHALL ARRANGE FOR UTILITY SURVEY TO IDENTIFY AND LOCATE ALL UTILITIES WITHIN THE PROPOSED TRENCH WORK. PRIOR TO CONDUCTING THE EXCAVATION WORK, THE CONTRACTOR SHALL POTHOLE IN THE AREAS WHERE KNOWN UTILITIES EXIST TO VERIFY THEIR ACTUAL LOCATIONS AND DEPTH.

6. THE CONTRACTOR SHALL BEAR THE COST OF REPAIR OR REPLACEMENT OF DAMAGE TO ALL UTILITIES DURING CONSTRUCTION ACTIVITIES.

7. CONTRACTOR SHALL PLACE ANY BACKFILL MATERIALS IN THE CONSTRUCTION STAGING AREA, AS SHOWN ON THE PLANS.

8. BASE CIVIL ENGINEER SHALL INDICATE TO THE CONTRACTOR TRENCH LOCATIONS WHICH INTERFERE WITH VEHICLE ACCESS. AT THESE LOCATIONS, CONTRACTOR SHALL PROVIDE TRENCH PLATES TO COVER TRENCHES UNTIL COMPLETION OF PAVING.

ABBREVIATIONS

amsl	ABOVE MEAN SEA LEVEL
ASTM	AMERICAN STANDARD FOR TESTING MATERIALS
acfm	ACTUAL CUBIC FEET PER MINUTE
bgs	BELOW GROUND SURFACE
BIO	BIOREMEDIATION NUTRIENT LINE
BLDG	BUILDING
DIA/ø	DIAMETER
E.W.	EASY WAY
E	ELECTRIC
EW	EXTRACTION WELL
ft	FEET
gal	GALLONS
HDPE	HIGH DENSITY POLYETHYLENE
Hp	HORSEPOWER
IRP	INSTALLATION RESTORATION PROGRAM
$KMnO_4$	POTASSIUM PERMANGANATE
MAX.	MAXIMUM
MIL	MILLIMETER
MIN.	MINIMUM
ML	FLOOD PLAIN SILTS
MW	MONITORING WELL
O.C.	ON CENTER
O.D.	OUTSIDE DIAMETER
OCEW	ON CENTER EACH WAY
PCC	PORTLAND CEMENT CONCRETE
PE	POLYETHYLENE
PSG	PROJECT SCREENING GOAL
PSI	POUNDS PER SQUARE INCH
PSIG	POUNDS PER SQUARE IN GAUGE
PVC	POLYVYNYL CHLORIDE
PVH	POLYVINYL CHLORIDE HOSE
RCP	REINFORCED CONCRETE PIPE
scfm	STANDARD CUBIC FEET PER MINUTE
SP	SAND
SCH	SCHEDULE
SVE	SOIL VAPOR EXTRACTION
VP	VAPOR MONITORING POINT
W	WATER
W/	WITH
μg/L	MICROGRAMS PER LITER

SITE PLAN SYMBOLS

SD	STORM DRAIN MANHOLE
	AIR NATIONAL GUARD BASE BOUNDARY
— —18.5— —	EXISTING SURFACE CONTOUR WITH ELEVATION IN FEET ABOVE MEAN SEA LEVEL
——18——	NEW SURFACE CONTOUR WITH ELEVATION IN FEET ABOVE MEAN SEA LEVEL
-----E-----	UNDERGROUND ELECTRICAL LINE
-----SS-----	UNDERGROUND SANITARY SEWER LINE, EXISTING
-----SD-----	UNDERGROUND STORM DRAIN LINE, EXISTING
=====SD=====	UNDERGROUND STORM DRAIN LINE, NEW
—— W ——	UNDERGROUND WATER LINE, EXISTING
250	BUILDING/STORAGE
	BITUMINOUS CONCRETE PAVEMENT
	CONCRETE PAVEMENT
	SILT FENCE
	CATCH BASIN

DETAIL REFERENCES

1

DETAIL OR SECTION NUMBER

INDICATES DETAIL FOUND ON SAME SHEET

1

C-1 C-3

DETAIL OR SECTION NUMBER

SHEET ON WHICH DETAIL/SECTION IS LOCATED

SHEET FROM WHICH DETAIL/SECTION IS REFERENCED

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GENERAL NOTES, LEGEND, & ABBREVIATIONS

SCALE AS NOTED	DESIGNED BY H. LEE	DRAWN BY J. ESTRADA	DRAWING NUMBER D-6101.52.02	SHEET 2 of
DATE 08/22/01	CHECKED E. IPSEN	APPROVED A. CHEMBURKAR, PE	JOB NUMBER 6101.52	REV

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ENVIRONMENTAL RESOURCES MANAGEMENT

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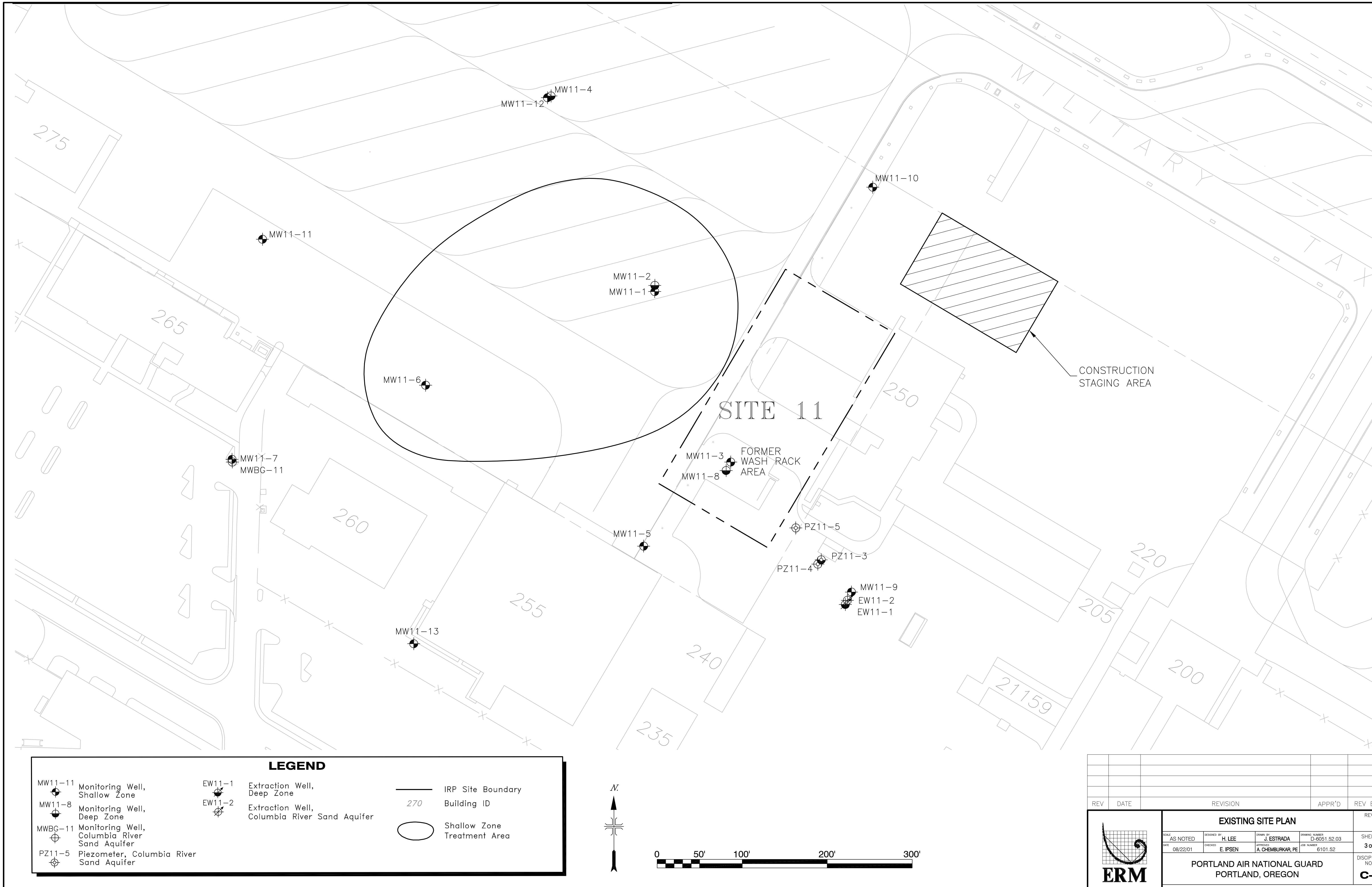

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	DATE 08/22/01	CHECKED E. IPSEN	APPROVED A. CHEMBURKAR, PE	JOB NUMBER 6101.52
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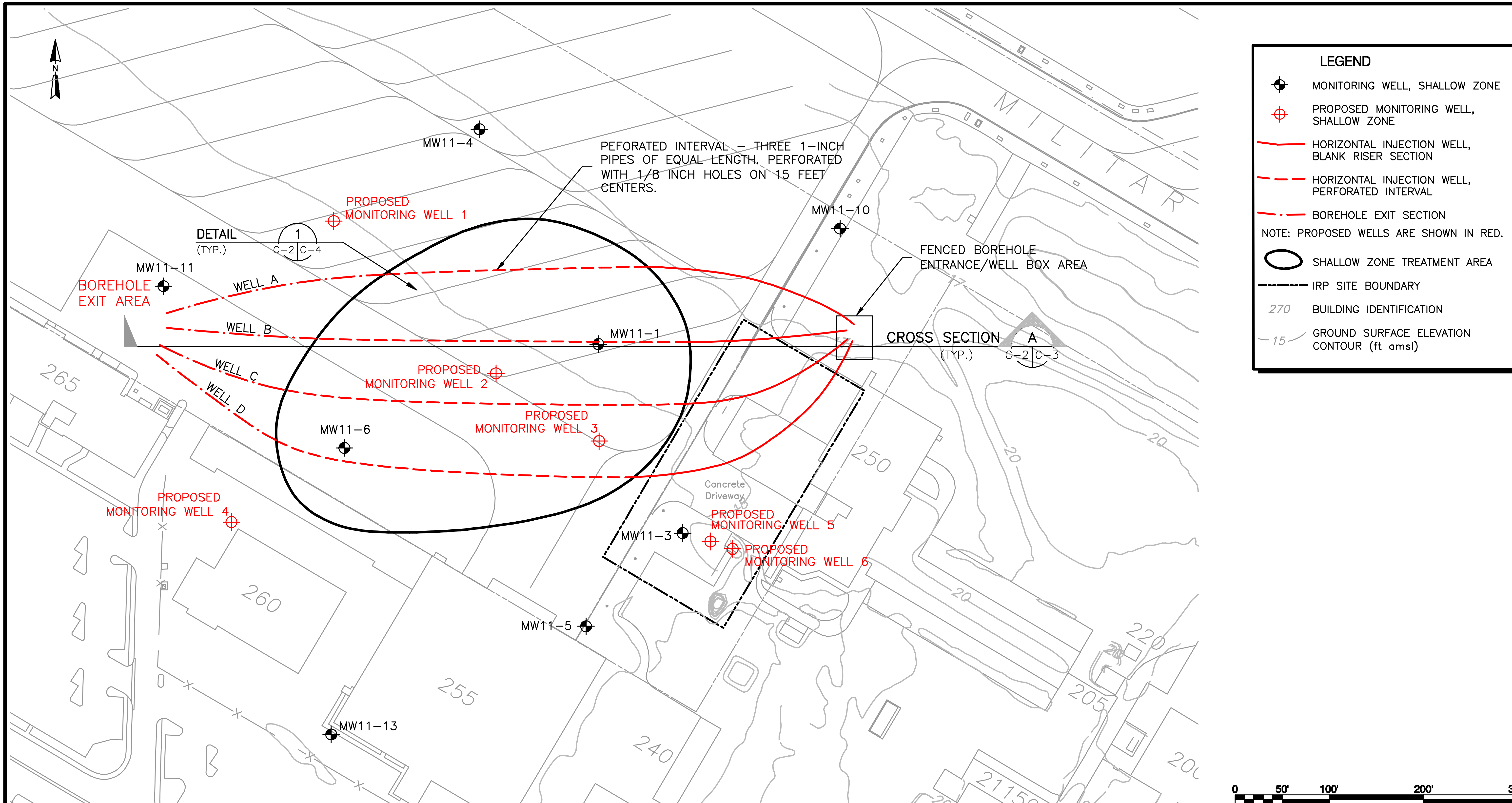

MONITORING WELL LOCATION	EASTING	NORTHING
PROPOSED WELL 1	76671085.09	704462.28
PROPOSED WELL 2	7667257.13	704300.73
PROPOSED WELL 3	7667366.60	704228.91
PROPOSED WELL 4	7666976.54	704142.92
PROPOSED WELL 5	7667484.66	704122.36
PROPOSED WELL 6	7667508.29	704114.55

INJECTION WELL LOCATION	PERFORATION INTERVAL		TOTAL PERFORATED LENGTH	LENGTH OF EACH PERFORATED PIPE
	EASTING	NORTHING		
WELL A	7667417.61 7667140.92	704413.91 704405.73	276	92
WELL B	7667462.34 7667070.23	704333.84 704337.57	393	131
WELL C	7667457.60 7667036.42	704264.84 704282.54	423	141
WELL D	7667403.59 7667026.47	704190.69 704228.37	381	127

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PERMANGANATE INJECTION SITE PLAN

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08/09/02	E. IPSEN	A. CHEMBURKAR, PE	6101.52

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ENVIRONMENTAL RESOURCES MANAGEMENT

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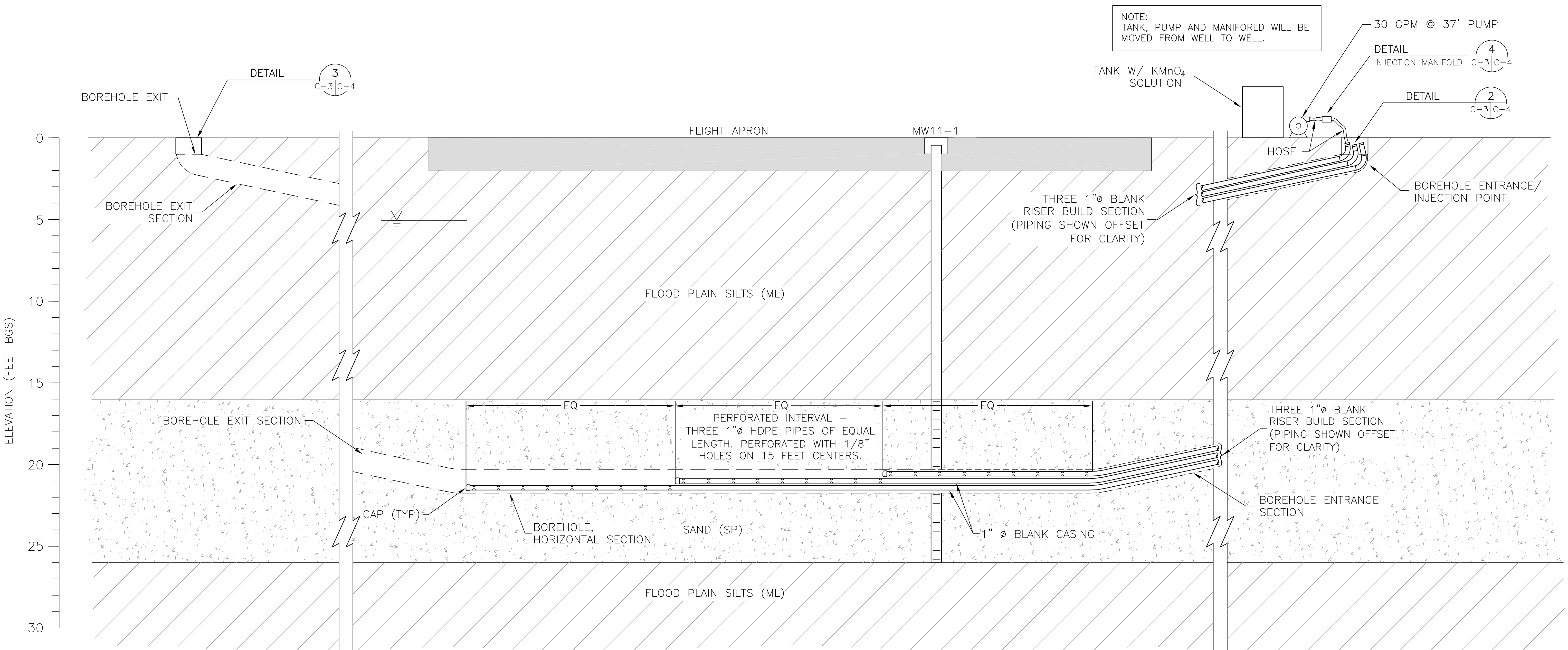

CROSS SECTION A C-2 C-3

LEGEND

- SILT/CLAYEY SILT/SANDY SILT
- POORLY GRADED GRAVELY SAND/SAND (SHALLOW WATER BEARING ZONE)

0 60'
Approximate Horizontal Scale

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HORIZONTAL INJECTION WELL TYPICAL CROSS SECTION

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AS NOTED	H. LEE	J. ESTRADA	D-6101.52.05	
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DISCIPLINE NO. C-3

ENVIRONMENTAL RESOURCES MANAGEMENT

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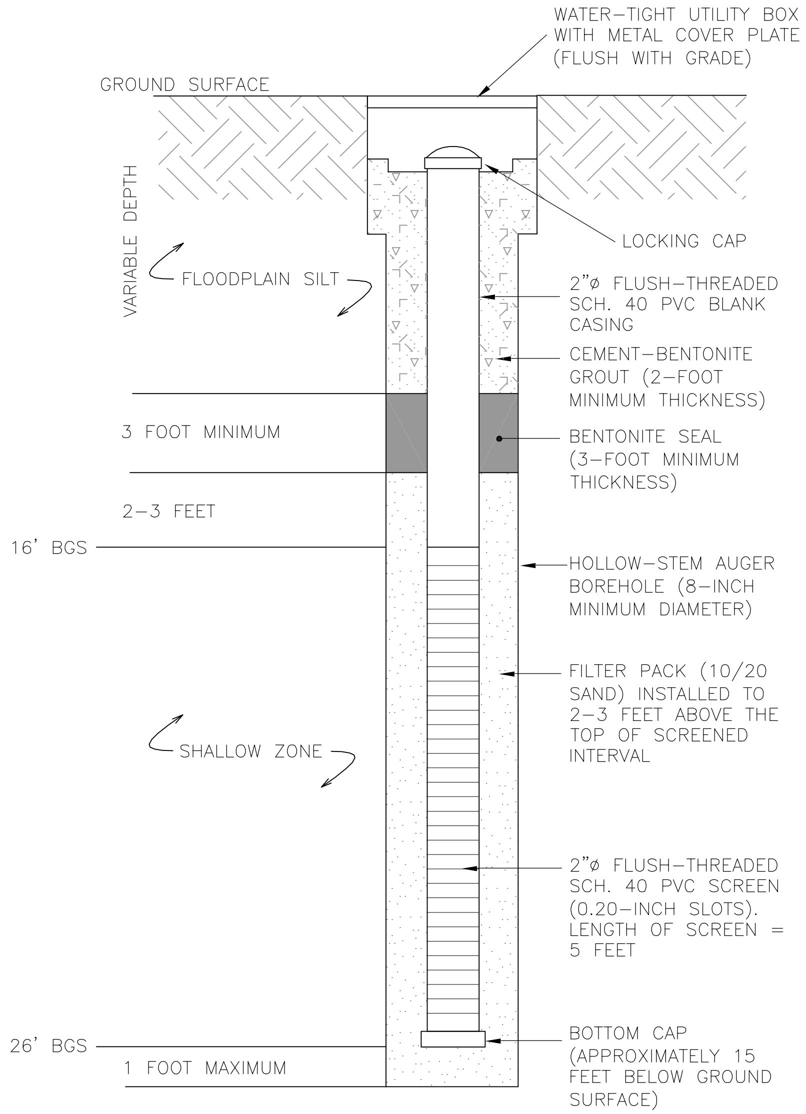

GROUNDWATER MONITORING WELL CONSTRUCTION DETAIL

DETAIL 1 C-2 C-4
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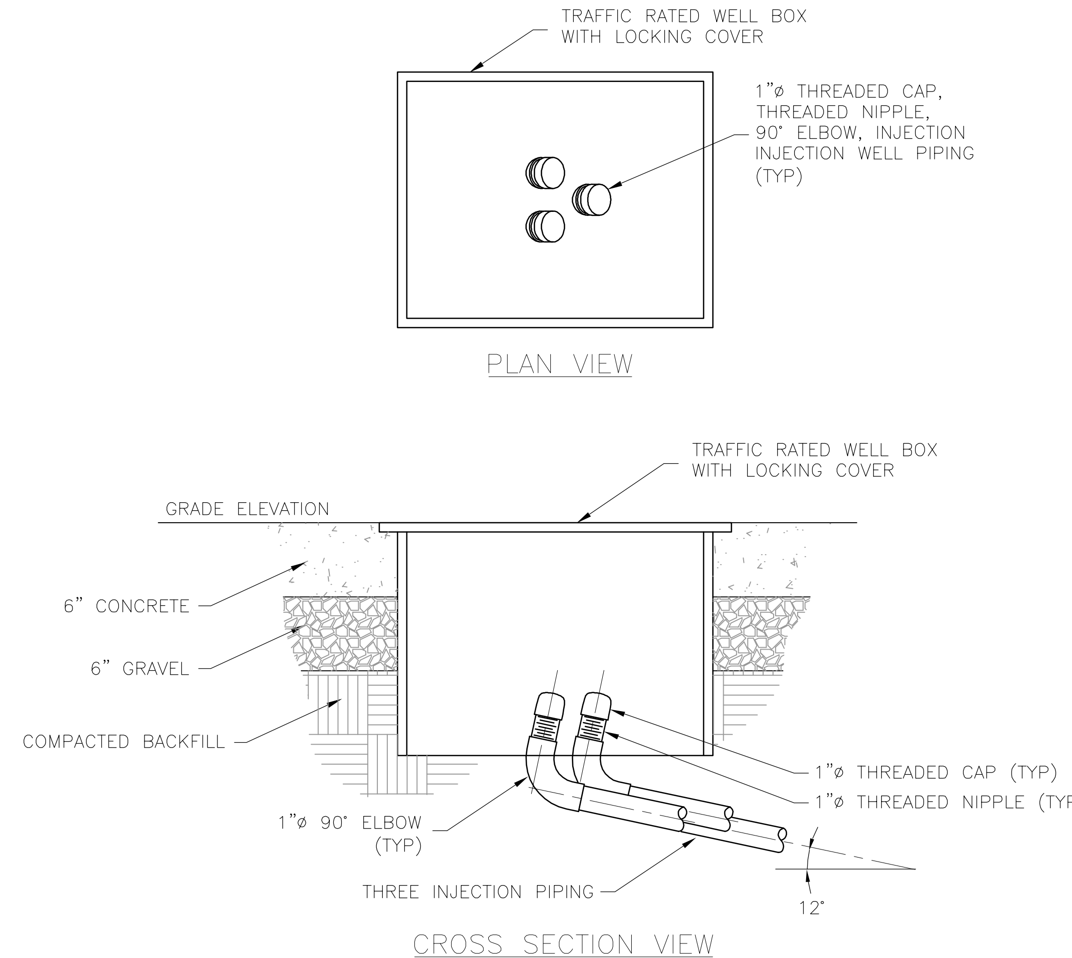

HORIZONTAL WELL BOX COMPLETION DETAIL (INJECTION SIDE)

DETAIL 2 C-3 C-4
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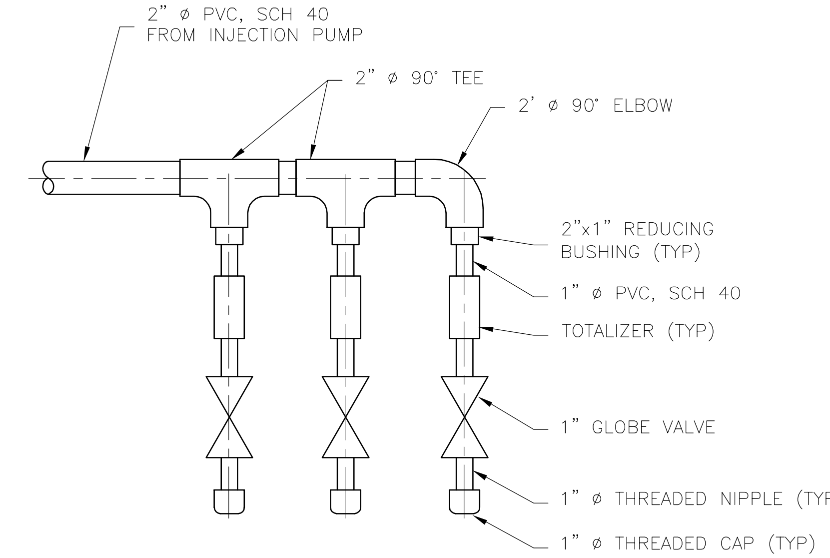

INJECTION MANIFOLD DETAIL

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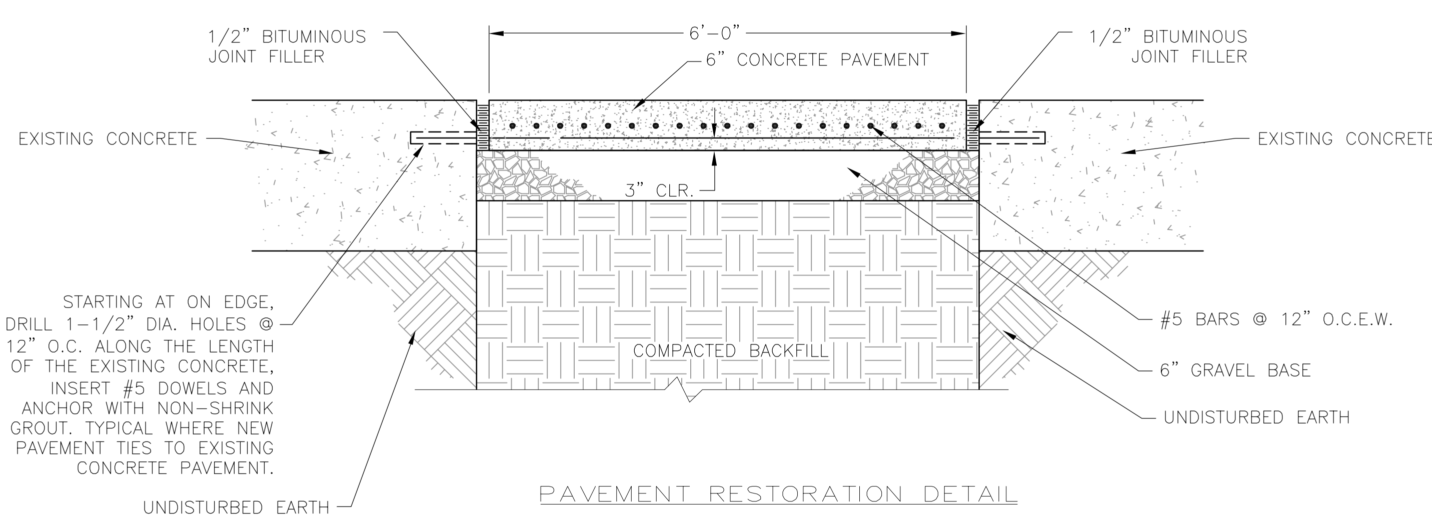

PAVEMENT RESTORATION DETAIL

DETAIL 3 C-3 C-4
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WELL CONSTRUCTION DETAILS			REV
SCALE AS NOTED	DESIGNED BY H. LEE	DRAWN BY J. ESTRADA	DRAWING NUMBER D-6101.52.07
DATE 08/22/01	CHECKED E. IPSEN	APPROVED A. CHEMBURKAR, PE	JOB NUMBER 6101.52
SHEET 7 of			
PORTLAND AIR NATIONAL GUARD PORTLAND, OREGON			DISCIPLINE NO. C-4

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ENVIRONMENTAL RESOURCES MANAGEMENT

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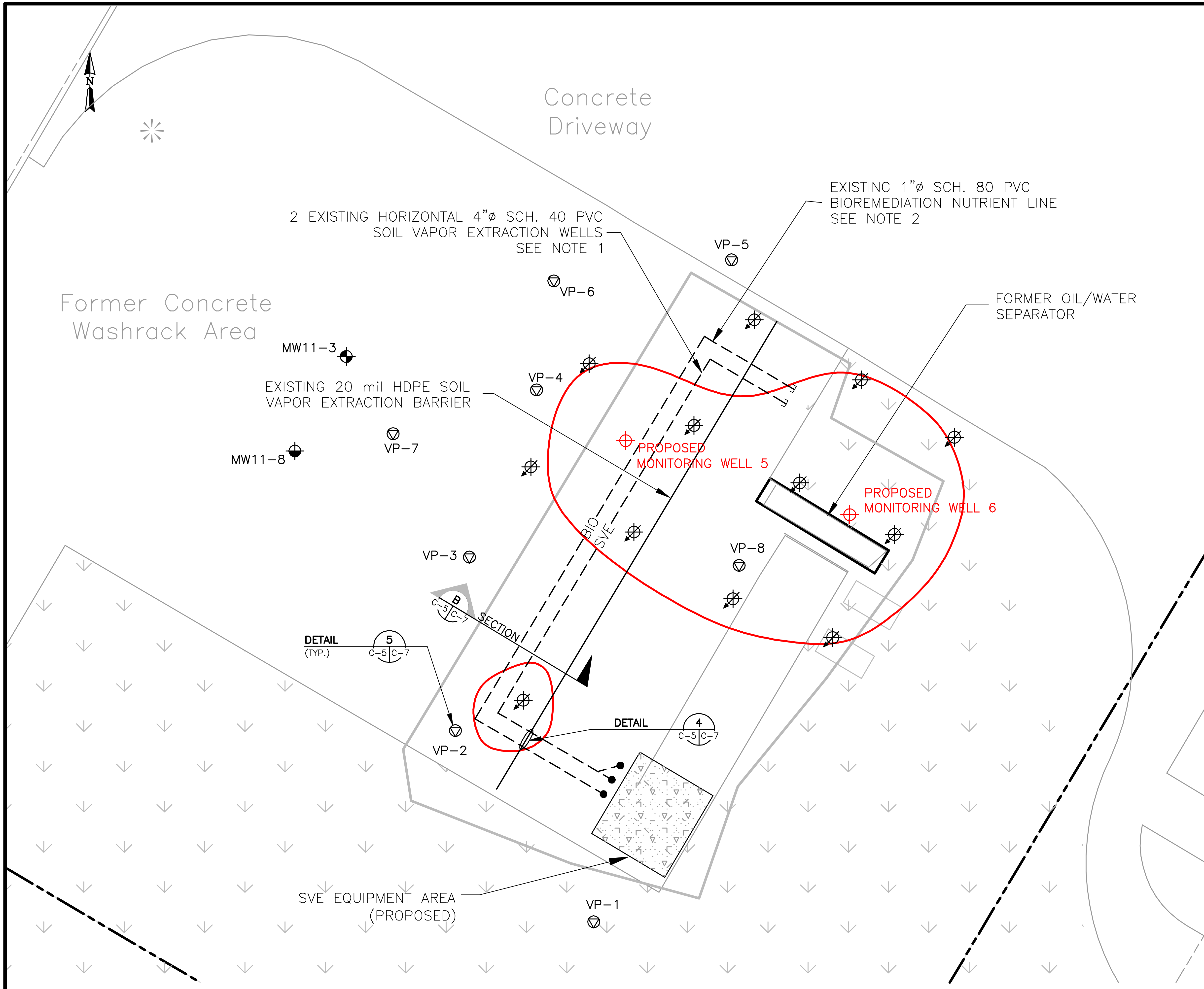

LEGEND

- APPROXIMATE EXTENT OF TOTAL PETROLEUM HYDROCARBONS and VOLATILE ORGANIC COMPOUNDS ABOVE PSGs IN SOIL (September 1999)
- EXCAVATION LIMITS, SEPTEMBER 1999
- GRASS
- SITE 11 BOUNDARY
- SVE EQUIPMENT AREA
- PROPOSED VAPOR MONITORING POINT
- PROPOSED ORC INJECTION POINT
- PROPOSED MONITORING WELL
- EXISTING MONITORING WELL SHALLOW ZONE
- EXISTING MONITORING WELL, DEEP ZONE

NOTE:

1. TWO (2) 4"ø SCHEDULE 40 VC HORIZONTAL IN-SITU SOIL VAPOR EXTRACTION WELLS AS INDICATED. SLOTTED CASING IS 0.020" MACHINE SLOTTED, ALL 4 SIDES. ALTERNATE SCREENED AND BLANK SECTION IN 20' LENGTH.
2. 1" SCHEDULE 80 PVC BIOREMEDIATION NUTRIENT INJECTION LINE AS INDICATED. 1/8"ø PERFORATIONS ON BOTTOM OF PIPE, SPACED 12" ON CENTER.

1" = 5' - 0" 0 1' 5' 10' 15'

REV	DATE	REVISION	APPR'D	REV BY

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SVE SYSTEM PLAN

SCALE	DESIGNED BY	DRAWN BY	DRAWING NUMBER
AS NOTED	H. LEE	JSE/RLO	D-6101.52.06
DATE	CHECKED	APPROVED	JOB NUMBER
08/09/02	E. IPSEN	A. CHEMBURKAR, PE	6101.52

REV

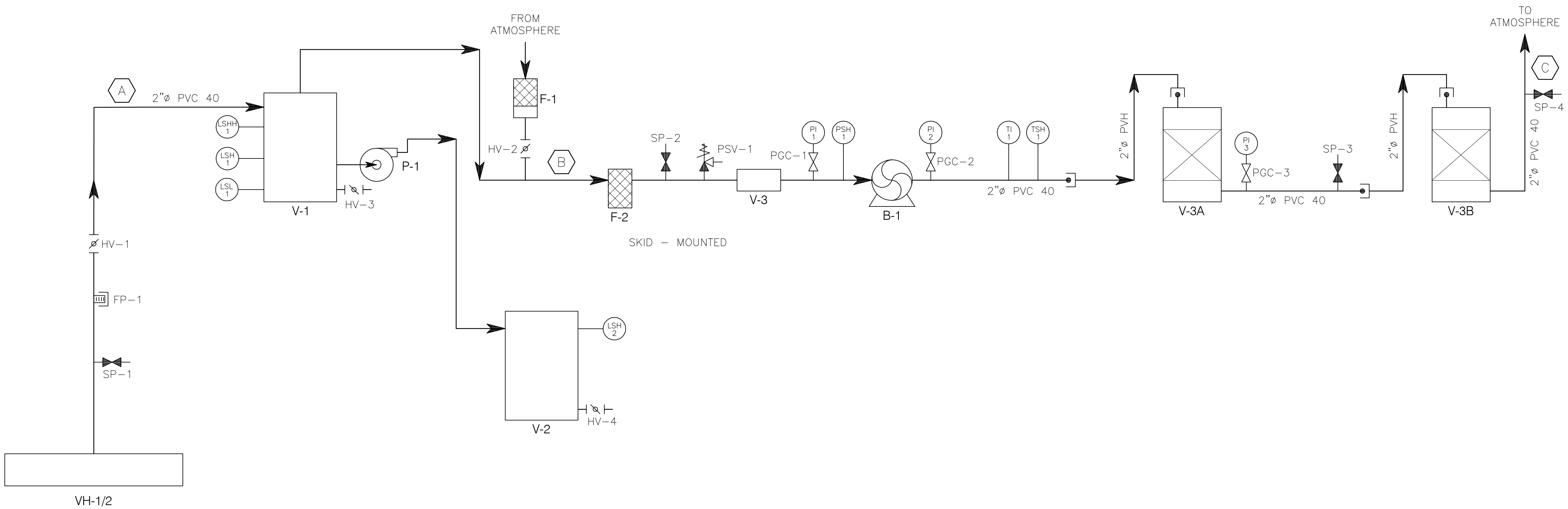
SHEET 6 of

PORTLAND AIR NATIONAL GUARD
PORTLAND, OREGON

DISCIPLINE NO. C-5

ENVIRONMENTAL RESOURCES MANAGEMENT

STREAM DESCRIPTION	FLOW CONDITIONS	CHEMICAL COMPOSITION (ppm)						
		BENZENE	cis-1,2-DCE	VINYL CHLORIDE	CHLOROBENZENE	1,4-DCB	TPH gasoline	PCE
A SOIL VENT GAS	25 scfm, 11.5 psig, 77°F	0.05	0.510	1.24	0.89	0.12	4,127	0.02
B BLOWER INFLUENT GAS	50 acfm, 5 psig, 77°F	0.05	0.510	1.24	0.89	0.12	4,127	0.02
C TREATED VENT GAS	50 acfm, 0.5 psig, 100°F	0.005	<0.005	<0.005	<0.005	<0.005	<0.5	<0.005



LEGEND

HV-XX BUTTERFLY VALVE

PSV-XX PRESSURE SAFETY VALVE

SP-XX SAMPLE PORT

PGC-XX PRESSURE GAGE COCK

CAM-LOCK CONNECTION

PI X PRESSURE INDICATOR

TI X TEMPERATURE INDICATOR

LSX XX LEVEL SWITCH

PSX XX PRESSURE SWITCH

FP-XX FLOW MONITORING POINT

ABBREVIATIONS

acfm = ACTUAL CUBIC FEET PER MINUTE
PVC 40 = POLYVINYL CHLORIDE PIPE (SCHEDULE 40)
PVH = POLYVINYL CHLORIDE HOSE
scfm = STANDARD CUBIC FEET PER MINUTE
Hp = HORSEPOWER
µg/L = MICROGRAMS PER LITER
psig = POUNDS PER SQUARE INCH GAUGE
gal = GALLONS

EQUIPMENT LIST

B-1	VACUUM EXTRACTION BLOWER
F-1	SUPPLEMENTAL AIR FILTER/SILENCER
F-2	SOIL GAS FILTER
P-1	KNOCK OUT DRUM SUMP PUMP
V-1	KNOCK OUT DRUM
V-2	WATER STORAGE POLY
V-3A/3B	VAPOR PHASE CARBON BEDS
V-3	VACUUM EXTRACTION INTAKE SILENCER

CONTROLS

LSHH 1 - LEVEL SWITCH HIGH-HIGH SHUTS DOWN SYSTEM

LSH 1 - LEVEL SWITCH HIGH ACTIVATES P-1

LSL 1 - LEVEL SWITCH LOW DEACTIVATES P-1

LSH 2 - LEVEL SWITCH HIGH SHUTS DOWN SYSTEM

PSH 1 - PRESSURE SWITCH HIGH SHUTS DOWN SYSTEM

TSH 1 - TEMPERATURE SWITCH HIGH SHUTS DOWN SYSTEM

B-1

50 scfm @ 6" Hg VACUUM
VACUUM EXTRACTION BLOWER

F-1

10 MICRON POLYESTER,
SUPPLEMENTAL AIR FILTER/SILENCER

F-2

SOIL GAS FILTER
10 MICRON POLYESTER,

V-1

KNOCK OUT DRUM
55 gal

V-2

WATER STORAGE POLY
1,000 gal CAPACITY

V-3

VACUUM EXTRACTION INTAKE SILENCER

V-3A/3B

VAPOR PHASE CARBON BEDS
200 lbs ACTIVATED CARBON (EACH BED)

VH-1/2

HORIZONTAL VACUUM
EXTRACTION WELL
4" DIAMETER

P-1

KNOCK OUT DRUM PUMP

REV	DATE	REVISION	APPR'D	REV BY

SVE SYSTEM PROCESS FLOW DIAGRAM and PIPING & INSTRUMENTATION DIAGRAM

SCALE AS NOTED	DESIGNED BY H. LEE	DRAWN BY J. ESTRADA	DRAWING NUMBER D-6051.52.08
DATE 08/22/01	CHECKED E. IPSEN	APPROVED A. CHEMBURKAR, PE	JOB NUMBER 6101.52

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DISCIPLINE NO. C-6

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ENVIRONMENTAL RESOURCES MANAGEMENT

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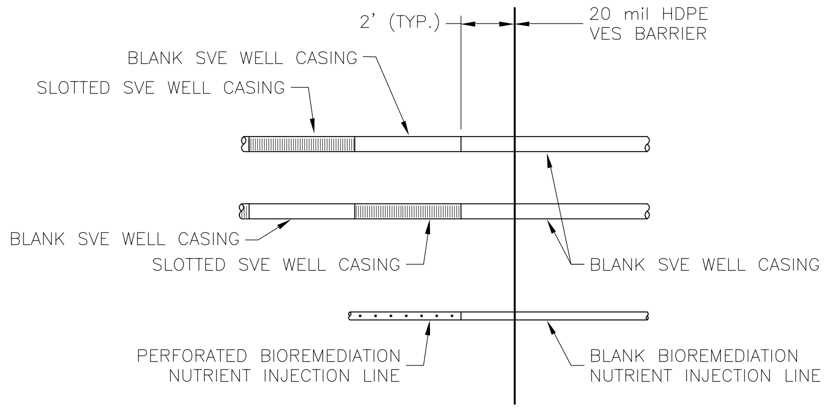
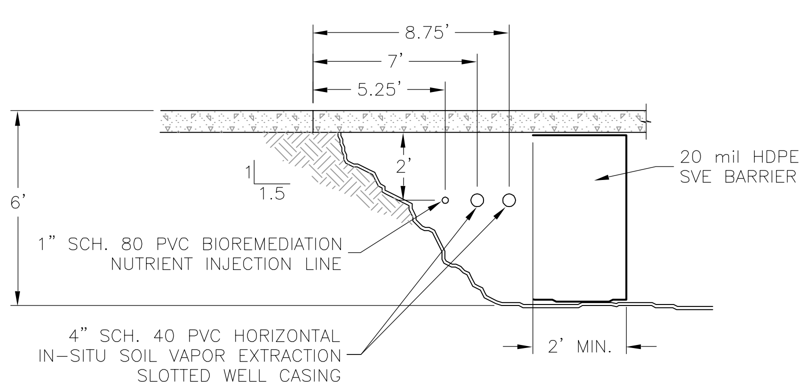


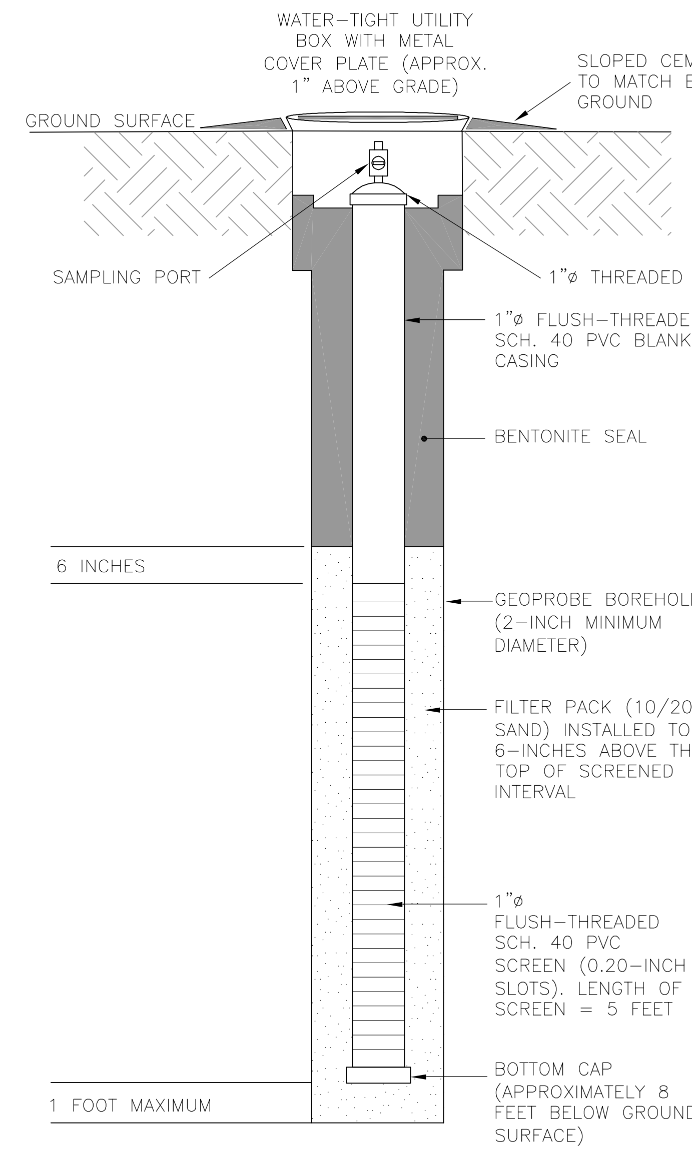
EXISTINGBIOREMEDIATION & SVE SYSTEM PIPING

DETAIL 4
N.T.S. C-5 C-7



EXISTINGBIOREMEDIATION & SVE SYSTEM PIPING SECTION

CROSS-SECTION B
N.T.S. C-5 C-7



VAPOR MONITORING POINT CONSTRUCTION DETAIL

DETAIL 5
N.T.S. C-5 C-7

REV	DATE	REVISION	APPR'D	REV BY

SVE SYSTEM DETAILS

SCALE	DESIGNED BY	DRAWN BY	DRAWING NUMBER	SHEET
AS NOTED	H. LEE	J. ESTRADA	D-6101.52.09	9 of
DATE 08/22/01	CHECKED E. IPSEN	APPROVED A. CHEMBURKAR	JOB NUMBER 6101.52	

PORTLAND AIR NATIONAL GUARD
PORTLAND, OREGON

DISCIPLINE NO. C-7

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ENVIRONMENTAL RESOURCES MANAGEMENT

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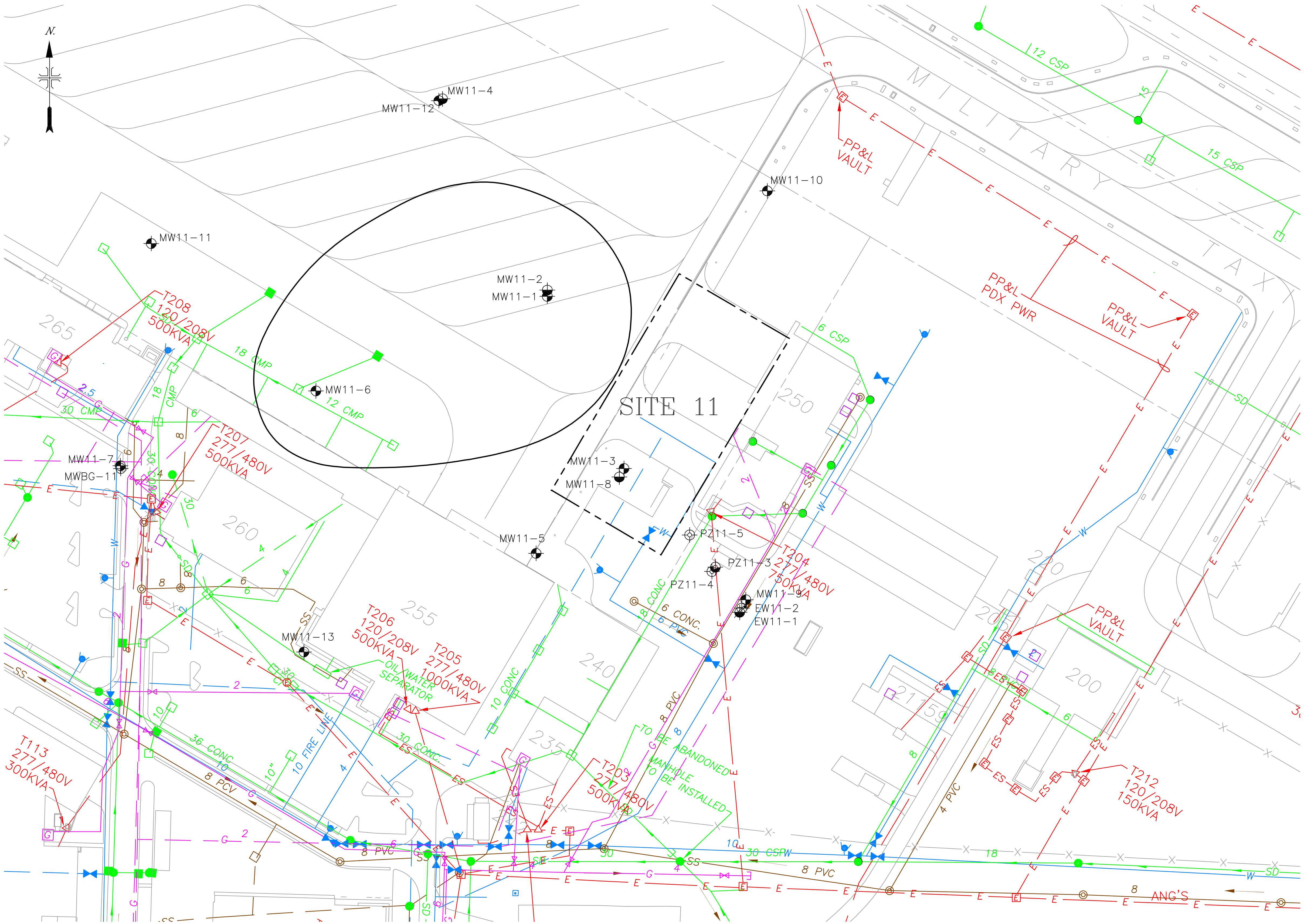

UTILITY SYMBOLS

DRAINAGE SYSTEM SYMBOLS

	MANHOLE
	CLEANOUT
12 SD	STORM DRAIN, WITH SIZE
	ABANDONED STORM
	FLOW DIRECTION
C	CONCRETE
CMP	CORRUGATED METAL PIPE
PP	PERFORATED PIPE
	STORM DRAIN CAPPED

SANITARY SEWER SYMBOLS

	MANHOLE
	CLEANOUT
8 SS	SANITARY SEWER, WITH SIZE
8 PS	PRESSURE SEWER, WITH SIZE
	ABANDONED SANITARY
	FLOW DIRECTION
AC	ASBESTOS CEMENT
PVC	POLYVINYL CHLORIDE
PS	PRESSURE SEWER
SS	SANITARY SEWER CAPPED

WATER SYSTEM SYMBOLS

	WATER VALVE
	FIRE HYDRANT WITH VALVE
	MONITORING WELL
6 CI W	WATER MAIN, WITH SIZE AND TYPE
	ABANDONED WATER MAIN
	ABANDONED AND CAPPED WATER MAIN
CI	CAST IRON
PVC	POLYVINYL CHLORIDE
T	TRANSITE
	IRRIGATION CONDUIT

ELECTRICAL SYSTEM SYMBOLS

OH/E	OVERHEAD ELECTRICAL POWER
OH/ES	OVERHEAD ELECTRICAL SECONDARY
E	UNDERGROUND ELECTRICAL POWER
ES	ELECTRICAL POWER SECONDARY
EP	ELECTRICAL POWER PROPOSED
E	U/G ELECTRICAL CONDUIT, CAPPED
	CAPPED SPARE CONDUIT
E	ELECTRICAL VAULT/MANHOLE
	ELECTRICAL TRANSFORMER
	EXISTING WOODEN POLE
	EXISTING WOODEN POLE W/LIGHT
	OUTDOOR ELECTRICAL CONNECTION

GAS SYSTEM SYMBOLS

	GAS VALVE
G	GAS METER
G	GAS MAIN CAPPED
6 G	GAS MAIN, WITH SIZE
	ABANDONED GAS MAIN
	ABANDONED AND CAPPED GAS MAIN

LEGEND

MW1-2	Monitoring Well, Shallow Zone	EW11-1	Extraction Well, Deep Zone		IRP Site Boundary
MW2-4	Monitoring Well, Deep Zone	EW11-2	Extraction Well, Columbia River Sand Aquifer	270	Building ID
MWBG-10	Monitoring Well, Columbia River Sand Aquifer				Shallow Zone Treatment Area
PZ11-5	Piezometer, Columbia River Sand Aquifer				

1" = 50' - 0" 0 10' 50' 100' 150'

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REV	DATE	REVISION	APPR'D	REV BY

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UTILITIES MAP

SCALE	DESIGNED BY	DRAWN BY	DRAWING NUMBER	SHEET
AS NOTED	H. LEE	J. ESTRADA	D-6101.52.10	10 of
DATE 08/22/01	CHECKED E. IPSEN	APPROVED A. CHEMBURKAR, PE	JOB NUMBER 6101.52	

PORTLAND AIR NATIONAL GUARD
PORTLAND, OREGON

DISCIPLINE NO. C-8

ENVIRONMENTAL RESOURCES MANAGEMENT

APPENDIX B

CONSTRUCTION SPECIFICATIONS

TABLE OF CONTENTS

Division 1

GENERAL REQUIREMENTS

SECTION 01000

SUMMARY OF WORK

PART 1 GENERAL

1.1 SCOPE OF CONTRACT WORK

The Contract Work under this project includes, but is not limited to, the remediation of areas impacted with chlorinated solvents and petroleum hydrocarbons at Installation Restoration Program (IRP) Site 11 at Portland Air National Guard Base (Portland ANGB), Portland International Airport, Portland, Oregon, as shown on the contract drawings included as Appendix A.

The Contractor shall furnish labor, materials, tools, equipment, supervision, transportation, and installation services required for the following tasks as summarized below and outlined in these Performance Specifications and Construction Drawings:

1. Mobilize to the site labor, equipment, materials, and other incidental items required to complete the Work. Attend construction meetings, including preconstruction and progress meetings, as directed by Owner. This is covered under Bid Item 1.

2. Install six groundwater monitoring wells at IRP Site No. 11 as shown on the Contract Drawings and specified in Section 02000 of the Specifications. This item also includes environmental testing, and transportation and disposal of impacted soil and water generated during activities. This is covered under Bid Item 2.

3. Install four horizontal injection wells at IRP Site No. 11 as shown on the Contract Drawings and specified in Section 02100 of the Specifications. This item also includes environmental testing, and transportation and disposal of impacted soil and water generated during activities. This is covered under Bid Item 3.

4. Inject potassium permanganate solution into the horizontal injection wells as specified in Section 02200 of the Specifications. This is covered under Bid Item 4.

5. Perform groundwater monitoring of 13 Shallow Zone wells as specified in Section 02300 of the Specifications. This item also includes environmental testing, and transportation and disposal of impacted water generated during activities. This is covered under Bid Item 5.

6. Install a soil vapor extraction (SVE) system as specified in the Contract Drawings and in Section 02400 of the Specifications. This system will include the following: existing SVE piping, vapor monitoring points (VMPs), vacuum blower, moisture recovery drum, granular activated carbon (GAC) units, piping, and miscellaneous gages. Also, install, connect, and activate electrical wiring and instrument controls for the SVE system. This is covered under Bid Item 6.

7. Operate the SVE system and provide monthly maintenance visits while the SVE system is in operation as specified in Section 02500 of the Specifications. This is covered under Bid Item 7.

8. Inject oxygen-releasing material as shown in Contract Drawings and specified in Section 02600 of the Specifications. This is covered under Bid Item 7.

1.2 EXISTING WORK

Contractor shall be required to protect existing Work and facilities at all times during the construction. In addition, the Contractor shall:

A. Remove or alter existing Work in such a manner as to prevent injury or damage to any portions of the existing Work that remain.

B. Repair or replace portions of existing Work, which have been altered during construction operations to match existing or adjoining Work, as approved by the Engineer. At the completion of operations, existing Work shall be in a condition equal to or better than that which existed before new Work started. Special care shall be taken to protect or repair the flight apron, as necessary. Repairs to the flight apron shall be performed in accordance with Base regulations.

1.3 LOCATION OF UNDERGROUND FACILITIES

Location of underground utilities shown on Drawing C-8 (Appendix A) is based on a utility survey conducted by the Base Civil Engineering

Department as well as a review of as-built drawings. The locations have not been verified by test pits and Owner assumes no responsibility for the accuracy of the drawings. The Contractor shall be responsible for scanning the construction site with appropriate utility locating equipment (such as electromagnetic or sonic equipment), and marking the ground surface where existing underground utilities are discovered. The Contractor shall perform test pits, as necessary, to verify and document the elevation of any utilities shown or discovered during the utility survey.

1.4 SUBMITTALS

Submit the following in accordance with the Section 01400**.**

A. List of Contact Personnel

B. Construction Schedule

1.5 CONTRACTOR PERSONNEL REQUIREMENTS

A. Subcontractors and Personnel

The Contractor shall furnish a list of contact personnel of the Contractor and Subcontractors including addresses and telephone numbers for use in the event of an emergency. As changes occur and additional information becomes available, the Contractor shall correct and change the information contained in previous lists.

B. Gate Passes

Gate passes will be furnished by Base Security at no additional cost to the Contractor. Contractor personnel must be familiar with and comply with Base security requirements at all times. Contractor vehicles must display a valid gate pass in accordance with Base security requirements.

1.6 CONTRACTOR ACCESS AND USE OF PREMISES

A. The Contractor shall ensure that Contractor personnel become familiar with and obey Base regulations. These regulations include, but are not limited to:

1. Keep within the limits of the Work and avenues of ingress and egress.

2. Do not enter restricted areas unless required to do so and until cleared for such entry.

3. Permission to interrupt any station roads or utility services shall be required in writing a minimum of 5 calendar days prior to the desired date of interruption.

4. The Contractor's equipment shall be conspicuously marked for identification.

B. Working Hours

Regular working hours shall consist of a period established by Owner between 7 a.m. and 5 p.m., Monday through Friday, excluding Government holidays.

C. Work Outside Regular Hours

Work outside regular hours will require Owner's approval. Provide written request 5 calendar days prior to such Work to allow arrangements to be made by the Base for inspecting the Work in progress.

D. Utility Cutovers and Interruptions

Utility cutovers may be made during regular hours provided written approval of the proposed cutover is granted by Owner and the cutover does not adversely affect Base operations.

1.7 CONSTRUCTION FACILITIES AND CONTROLS

A. Temporary Electricity

The Contractor may install temporary electrical service at his sole cost. Owner shall be responsible for paying for reasonable amounts of electrical usage.

B. Telephone Service

The Contractor shall use local pay telephones or use self-supplied mobile phones.

C. Temporary Water Service

Water shall be available from a hydrant on site, as identified by Owner. The Contractor shall provide for hookup, metering, and use of water from hydrant. The Contractor shall be responsible for providing drinking water for his use. The Contractor shall use measures to conserve water.

D. Temporary Sanitation Facilities

The Contractor shall provide temporary sanitation facilities at location(s) approved by Owner. The Contractor shall maintain facilities in clean and sanitary condition.

E. On-Site Storage of Equipment and Materials

The Contractor shall coordinate the storage of equipment and materials on base with Owner.

F. Progress Cleaning

The Contractor shall maintain the site free of waste materials, debris, and rubbish. The Contractor shall remove waste materials, debris, and rubbish from the site at least weekly or at Owner's request and dispose of off site in a manner in accordance with regulations and at the Contractor's expense.

PART 2 PRODUCTS – NOT USED

PART 3 EXECUTION – NOT USED

END OF SECTION

SECTION 01100

MEASUREMENT AND PAYMENT

PART 1 GENERAL - NOT USED

PART 2 PRODUCTS - NOT USED

PART 3 EXECUTION

3.1 CONTRACT PAY ITEM - MOBILIZATION/MEETINGS

A. Pay Item 1 - Mobilization/Meetings

1. Measurement

The Work required for this item will be measured on the basis of satisfactory evidence of mobilization of sufficient labor, equipment, and material to adequately advance the Work. Also included in this bid item is attendance to construction meetings, including preconstruction and progress meetings, as directed by Owner.

2. Payment

The Lump Sum Price for mobilization and meeting attendance shall be payment in full for labor, equipment, material, and other incidentals.

3.2 CONTRACT PAY ITEM - WELLS

A. Pay Items 2 and 3 – Well Installation

1. Measurement

Four horizontal injection wells and six monitoring wells shall be constructed. These bid items shall include loading, transportation, disposal, and other incidental costs such as analytical testing required by the disposal site. For bidding purposes, the Contractor shall provide itemized costs for disposal of soil at both a Class I Landfill and a Class II Landfill. Also for bidding purposes, the Contractor shall provide costs to dispose of water as hazardous and nonhazardous waste.

2. Payment

The Lump Sum Price shall be determined from the Unit Price for installing the injection wells and the monitoring wells. The Lump Sum Price shall include labor, material, equipment, permitting, and incidentals, such as polyvinyl chloride (PVC) pipe, PVC screen, high-density polyethylene (HDPE) pipe, grout, and analytical testing. The Contractor shall also provide Unit Prices for waste disposal.

B. Pay Item 4 – Potassium Permanganate Solution Injection

1. Measurement

Potassium Permanganate Solution shall be injected into the four horizontal injection wells. This item shall also include costs to complete the treatability test and the injection pilot test. For bidding purposes, the Contractor shall assume two separate injection events for each well.

2. Payment

The Lump Sum Price for potassium permanganate injection includes labor, materials, equipment, and other incidentals as required to inject as detailed on the contract drawings and Section 02200.

C. Pay Item 5 – Quarterly Groundwater Monitoring

1. Measurement

Ten Shallow Zone groundwater monitoring wells shall be sampled and analyzed quarterly for 2 years.

2. Payment

The Lump Sum Price for injection shall be payment in full for labor, equipment, material, and other incidentals required for monitoring as detailed in Section 02300.

3.3 CONTRACT PAY ITEM – SOIL VAPOR EXTRACTION SYSTEM

A. Pay Item 6 – Provide and Install SVE System

1. Measurement

Not applicable.

2. Payment

The Lump Sum Price for providing and installing the SVE system shall include labor, materials, equipment, installation, electrical work, instrumentation controls installation, testing, and other incidentals as required to construct the treatment system as detailed on the contract drawings and Section 02400.

B. Pay Item 7 – Operation and Maintenance

1. Measurement

The Unit Cost for each Operation and Maintenance (O&M) visit shall reflect the number of man-hours and quantity of materials required for each visit. Payment for the O&M visits shall be made based on the number of actual visits required. The Contractor shall provide a Unit Cost per visit and shall assume 12 visits (monthly while the system is operating during the low water table) shall be required over the 2-year period.

2. Payment

The Lump Sum Price for operating and maintaining the treatment system shall be full compensation for 12 O&M visits, including labor, materials, reports, equipment, testing, travel, and other incidentals as detailed in Section 02500.

3.4 CONTRACT PAY ITEM – OXYGEN RELEASE COMPOUND INJECTION

A. Pay Item 8 – Oxygen Release Compound (ORC) Injection

1. Measurement

ORC shall be injected into 12 injection points.

2. Payment

The Lump Sum Price for ORC injection includes labor, materials, equipment, and other incidentals as required to inject ORC as detailed on the contract drawings and Section 02600.

END OF SECTION

SECTION 01200

HEALTH AND SAFETY

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Health and Safety Requirements

B. Air Monitoring

C. Traffic Control

D. Health and Safety Plan

E. Foreign Object/Debris Management Plan

1.2 HEALTH AND SAFETY REQUIREMENTS

A. Hazardous Chemicals

1. Chemicals known to be hazardous may be encountered while performing the Work. Documents, describing in further detail the chemicals encountered, can be reviewed at Lieutenant Colonel Roger Rein's office.

B. Health and Safety

1. Contractor personnel working at the site shall comply with the 40-hour Occupational Safety and Health Administration (OSHA) 29 CFR 1910.120 Health and Safety Training Requirements.

2. The Contractor shall provide appropriate safety training and equipment including, but not limited to, the following: barricades; fire extinguishers; spark-proof tools; respirators; and personnel protective clothing (including, but not limited to: hard hats; steel toe and shank boots; safety glasses; and chemical-resistant coveralls). Potential hazards associated

with potassium permanganate and ORC chemicals should be addressed. Safety equipment shall be available and readily accessible prior to commencing Work.

3. The Contractor is responsible to ensure that personnel safety gear that meets OSHA requirements is used. The Contractor must ensure that tools and equipment are in good operating condition and in compliance with OSHA regulations.

4. The Contractor’s Work shall at all times be in compliance with applicable municipal, State, and Federal regulations, codes, laws, and ordinances, including applicable provisions of the OSHA Act of 1970 and subsequent revisions.

5. Ignition Sources: Ignition sources and gasoline-driven equipment shall be removed from areas where flammable vapors are likely to accumulate. Smoking is not permitted at the site.

1.3 AIR MONITORING

A. The Contractor shall provide air monitoring required to maintain compliance with the Contractor’s Health and Safety Plan. If air monitoring indicates concentrations that require additional personal protective equipment, the Contractor shall provide such equipment to its employees and Subcontractors at the Contractor's expense.

1.4 TRAFFIC CONTROL

A. The Contractor shall implement traffic control consistent with the requirements set forth by Owner.

1.5 HEALTH AND SAFETY PLAN

A. The Contractor shall prepare a Health and Safety Plan, which shall be subject to Owner’s review and approval. The Contractor shall adhere to the requirements of the Contractor’s Health and Safety Plan.

B. Within 15 days of contract award, submit Contractor's Health and Safety Plan (HSP) for Owner’s review and approval.

1.6 FOREIGN OBJECT/DEBRIS MANAGEMENT PLAN

A. The Contractor shall prepare a Foreign Object/Debris Management Plan (FOD), which shall be subject to Owner’s review and approval. The Contractor shall adhere to the requirements of the Contractor’s FOD.

B. Within 15 days of contract award, submit Contractor's FOD for Owner’s review and approval.

PART 2 PRODUCTS - NOT USED

PART 3 EXECUTION - NOT USED

END OF SECTION

SECTION 01300

PROJECT MEETINGS, SCHEDULES, AND REPORTS

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Pre-Construction Meeting

B. Progress Meetings

C. Work Progress Schedule

D. Monthly Progress Reports

1.2 SUBMITTALS

A. Form 3064 - Air Force Project Schedule Estimate Form

B. Form 3065 - Contract Progress Report

1.3 PRE-CONSTRUCTION MEETING

A. Owner shall administer a pre-construction meeting within 10 days of date of Contract Award to establish a working understanding between parties as to their relationships during conduct of the Contract Work.

1.4 PROGRESS MEETINGS

A. These are required by Government to document Contractor progress.

B. Schedule and administer progress meetings weekly or as requested throughout the process of the Contract Work.

1.5 WORK PROGRESS SCHEDULE

A. Within 15 days of Contract Award, Contractor shall submit a Work progress schedule, showing the dates for beginning and completing each major element of construction, and the installation dates for major items of equipment.

B. The schedule shall show the Work in a graphic format suitable for displaying scheduled and actual progress.

C. Contractor shall submit Work Progress Reports in accordance with Section 01400 as directed by Owner (assume one per week).

1.6 MONTHLY PROGRESS REPORTS

A. Contractor shall submit monthly progress reports to the Oregon Department of Environmental Quality (ODEQ) during the first 6 months of Work beginning at the commencement of field work. Monthly progress reports shall include data collected during the previous month, a description of any problems encountered, and discussion of how the problems were remedied.

PART 2 PRODUCTS - NOT USED

PART 3 EXECUTION - NOT USED

END OF SECTION

SECTION 01400

SUBMITTALS

PART 1 GENERAL

1.1 SECTION INCLUDES:

A. Permitting and Notifications

B. Manufacturer's Instructions

C. Manufacturer's Certificates

D. Submittal Due Times

1.2 PERMITTING AND NOTIFICATIONS

The Contractor is responsible for obtaining permits and inspections that will be required in the performance of the Contract Work. The permit requirements for the monitoring well and injection well installations are outlined in their respective sections (Section 02000 and Section 02100). No permit is necessary for the SVE system but the Contractor is responsible for notifying and meeting ODEQ air laws. The Contractor shall provide Owner with copies of permits and satisfactory evidence of inspections, as necessary. Permits shall be obtained in a timely manner and as specified in this section.

1.3 MANUFACTURER'S INSTRUCTIONS

A. When specified in individual specification sections, submit manufacturer's printed instructions for delivery, storage, assembly, installation, startup, adjusting, and finishing in quantities specified for Product Data.

B. Identify conflicts between manufacturer's instructions and Contract Documents.

1.4 MANUFACTURER'S CERTIFICATES

A. Where specified in individual specification Sections, submit manufacturer's certificates for Owner review.

B. Indicate material or product conforms to or exceeds specified requirements. Submit supporting reference date, affidavits, and certifications, as appropriate.

C. Certificates may be recent or previous test results on material or product, but must be acceptable to the Government.

1.5 SUBMITTAL DUE TIMES

A. The tables below list the submittals required by the project specifications. Any submittal required to be submitted by the Contractor, but which is not listed on the table, shall be submitted in accordance with the applicable requirements of this specification.

B. Division 1

Specification Reference Section	Submittal Requirement	Submittal Due Time
01200	Contractor's Health and Safety Plan	3 weeks following Contract Award.
01200	FOD Plan	3 weeks following Contract Award.
01300	Form 3064 - Air Force Project Schedule Estimate Form	3 weeks following Contract Award.
01300	Form 3065 – Contract Progress Report	Monthly; weekly during field activities.
01300	Work Progress Schedule	3 weeks following Contract Award.
01300	Progress Meeting Minutes	4 weeks following meeting.
01300	Monthly Progress Reports	Monthly during field work.
01400	Evidence of Receipt of Required Permits and Notifications	1 week prior to performance of applicable portion of Contract Work.

C. Division 2

Specification Reference Section	Submittal Requirement	Submittal Due Time
02000/02100	Well Permits	At least 3 days prior to initiation of well installation.
02000/02100	Proof of State License to Perform Work	3 weeks following Notice to Proceed.
02000/02100	Summary Reports for Monitoring and Injection Well Installation	6 weeks following installation.
2100	Drilling Fluid Manufacturer's Specifications	3 weeks following Notice to Proceed.
02300	Monitoring Well Quarterly Reports	6 weeks following end of quarter.
02400	Manufacturer's Data Product Literature	6 weeks following Notice to Proceed.
02400	Shop Drawings	6 weeks following Notice to Proceed.
02400	Manufacturer's Warranty	6 weeks following Notice to Proceed.
02400	Draft SVE Electrical Construction Design and Details	6 weeks following Notice to Proceed.
02400	Draft SVE System O&M Manual	2 weeks prior to startup.
02400	Final SVE System O&M Manual	2 weeks following startup.
02400	Quarterly O&M Summary Report	6 weeks following end of quarter.

PART 2 PRODUCTS - NOT USED

PART 3 EXECUTION - NOT USED

END OF SECTION

Division 2

SITE WORK

SECTION 02000

MONITORING WELL INSTALLATION

PART 1 GENERAL

1.1 SUMMARY

The Contractor shall furnish labor, tools, equipment, supervision, transportation, materials, and installation services required to install the groundwater monitoring wells described in this section. The locations of the six wells are shown on Drawing C-2 and the construction details are shown on Drawing C-4 (Appendix A). Monitoring well installation activities shall be performed in accordance with the *Final 2001-2002 Groundwater Monitoring Work Plan*, dated July 2001.

1.2 SUBMITTALS

A. Monitoring Well Start Cards

B. Proof of State license to perform Work covered by this Section

C. Summary report at conclusion of installation

1.3 QUALITY ASSURANCE

A. Perform Contract Work in accordance with the plans and specifications. The Engineer shall be on site during drilling operations.

1. Upon request, provide information to the Engineer regarding actual locations of groundwater monitoring wells, depths, well construction details, and drilling difficulties encountered.
2. Submit signed copy of driller's logbook statements for monitoring well permits.

PART 2 PRODUCTS

2.1 MATERIALS

A. Monitoring well casing: 2-inch-diameter, Schedule 40 PVC, threaded, flush joint, as indicated.

B. Monitoring well screen: 2-inch-diameter, threaded, flush joint, PVC screen, 0.010 slot, as indicated.

C. Bentonite grout: A commercially available bentonite grout mixture developed for environmental monitoring well applications shall be used where indicated. The bentonite grout mixture shall be prepared according to manufacturer's instructions for installation by tremie pipe.

D. Bentonite seal: Mixture of bentonite powder and potable water at a slurry consistency to allow placement with a tremie pipe and as approved by the Engineer.

E. Filter pack: No. 5 quartz sand.

F. Locking cap: Watertight PVC locking cap and keyed-alike padlock. The padlock shall be consistent with existing master locks used at the site.

G. Surface completion: Watertight aircraft-rated utility boxes with metal cover plates approximately 1 inch above grade, secured with mortar collars and concrete pads that are flush with the ground surface. Stainless steel bolts will be used on all well covers installed on the flight apron.

PART 3 EXECUTION

3.1 MONITORING WELL LOCATIONS

The monitoring wells will be within the Shallow Zone treatment area, as shown on Drawing C-2 (Appendix A). The wells will be within a 5-foot radius of the following survey coordinates:

Monitoring Well Location	Easting	Northing
Proposed Well 1	76671085.09	704462.28
Proposed Well 2	7667257.13	704300.73
Proposed Well 3	7667366.60	704228.91
Proposed Well 4	7666976.54	704142.92
Proposed Well 5	7667484.66	704122.36
Proposed Well 6	7667508.29	704114.55

3.2 PERMIT REQUIREMENTS

The installation of groundwater monitoring wells will require submittal of a Start Card – Notice of Beginning of Well Construction by the drilling Subcontractor to the Oregon Water Resources Department, prior to installing wells. Work clearances are required by the Portland ANGB prior to drilling to ensure adequate precautions have been taken to protect underground utilities. Work clearance requests will be submitted for Portland ANGB approval prior to mobilizing the drilling Subcontractor to the site.

3.3 DRILLING ACTIVITIES

The boreholes shall be drilled using a hollow-stem auger rig. Soil samples shall be collected during drilling and used for the purpose of lithologic logging.

Utilities in the vicinity of the drilling site shall be located prior to mobilization of the drilling Subcontractor to the Portland ANGB. Any necessary excavation/boring permits shall be completed and submitted to the appropriate Portland ANGB personnel for approval.

In the event that drilling at any of the planned locations will interfere with subsurface utilities, the wells shall be relocated as close as possible to the original locations. Relocated drilling locations shall be approved by the Portland ANGB Civil Engineer or designated representative. Planned drilling locations shall be staked or painted in the field for inspection and approval by the Portland ANGB Civil Engineer.

3.4 BOREHOLE LOGGING

A Geologist or Engineer shall be present at the drilling rig for logging samples, monitoring drilling operations, recording soil and groundwater data, monitoring and recording well installation procedures, and preparing boring logs and well construction diagrams. The Geologist or Engineer shall have sufficient tools and professional equipment in operable condition to efficiently perform these duties, and shall be under the direct supervision of an Oregon-registered Geologist.

The lithologic data recorded during the drilling of each borehole will be based on the visual inspection of soil samples supplemented by the examination of drill cuttings. Boring logs will also include recorded blow counts and hammer weight and drop. Material will be classified using the Unified Soil Classification System and described according to the American Society for Testing and Materials Standard D2488-69, "Description of Soils (Visual Manual Procedure)".

3.5 SAMPLING

During the monitoring well installation, bulk soil and bulk groundwater samples will be collected and sent to a laboratory to perform a treatability test. The treatability test will be performed to quantify the native soil demand for potassium permanganate. More details regarding the treatability test are included in Section 02200.

The groundwater samples will also be analyzed for chlorinated volatile organic compounds (VOCs) using United States Environmental Protection Agency (USEPA) Test Method 8260. This data will be used in the final determination of the horizontal injection well locations.

3.6 MONITORING WELL COMPLETION

No solvents, cements, or adhesive tapes will be used to connect sections of the well casing or screen. The well casing materials will be decontaminated as necessary before being installed in the borehole.

A sand filter pack will be installed in each well by filling the annular space between the well screen and the borehole wall with clean, well-sorted, silica sand to approximately 1 to 3 feet above the top of the well screen.

A bentonite filter pack seal at least 2 feet thick will be installed above the sand filter pack. The remaining annular space above the bentonite seal will be filled with concrete.

Wells shall be completed in watertight, traffic-rated utility boxes with metal cover plates approximately 1 inch above grade, with tamper-proof, watertight caps. Well vaults shall be secured with mortar collars and concrete pads that are flush with the ground surface. Monitoring wells installed on the flight apron will be constructed according to Air National Guard (ANG) specifications to support loads related to aircraft traffic. Stainless steel bolts will be used on all well covers installed on the flight apron.

3.7 MONITORING WELL DEVELOPMENT

Following well completion, the wells shall be developed in accordance with the *Final 2001-2002 Groundwater Monitoring Work Plan*, using the following guidelines:

A. The initial development of the completed monitoring wells will be performed as soon as possible, but no sooner than 24 hours after the placement of the borehole grout seals. Well development activities will be documented. Initially, each well and associated worker breathing zone will be monitored with a photoionization detector (PID) to establish if any organic vapors are present. If vapors are detected, procedures outlined in the HSP will be implemented. The wells will be developed using either a submersible pump, jetting, back-surging, a bailer, and/or a surge block. The lithology adjacent to the screened interval, the amount of fine sediment, and the clarity of the water in the well casing prior to any development will dictate the development method to be used. Well development will consist of repeated evacuation and surging.

B. A minimum of three well volumes will be purged plus any additional volume necessary until the groundwater parameters have stabilized and the water is clear. During the development process, the specific conductance, pH, and water temperature will be measured every well volume. The well will be considered adequately developed when the measured parameters are stabilized, the necessary quantity of water is removed, and the water is visibly clear of sand and sediments. A bailer will remove the sediment at the bottom of the well to a point where less than one percent of the screen length of sediment remains in the well. Stabilization parameters and associated permitted deviations include:

1. pH: +/- 0.1 unit

2. Temperature: +/- 1o C

3. Specific Conductivity: +/- 10%

C. The goal for well development is a turbidity of equal to or less than 5 Nephelometric Turbidity Unit. If the measured parameters are stabilized and the proper amount of water is withdrawn but the water is still cloudy, then an additional amount of water equal to two standing water volumes will be removed, at which point the well will be considered fully developed.

3.8 EQUIPMENT DECONTAMINATION

Downhole drilling equipment shall be steam-cleaned or pressure-washed with hot water prior to drilling and between drilling locations. Decontamination shall take place in a designated decontamination area away from the wells. Decontaminated drilling equipment and unused construction materials shall be removed from the Portland ANGB at the completion of drilling activities.

Decontamination of sampling equipment will include the following (in order of performance):

A. Alconox (or equivalent) and tap water wash;

B. Tap water rinse;

C. American Society for Testing and Materials Type II reagent-grade water rinse; and

D. Isopropanol or methanol spray rinse.

3.9 SURVEYING

Surveying activities will be conducted by a licensed surveyor upon completion of the installation. The wells will be surveyed both horizontally and vertically using existing control monuments at the Portland ANGB. The location of the top of the well casings will be established to the nearest ±0.01 foot vertically and to the nearest ±0.1 foot horizontally.

3.10 INVESTIGATION-DERIVED WASTE

Drill cuttings, well purge water, and equipment decontamination water shall be contained in 55-gallon drums and shall be stored at a designated location at the Portland ANGB. Each drum shall be immediately labeled with the contents, source, generation date, and contact phone number. Investigation-derived waste will be sampled and characterized. The Contractor shall provide proper transportation and off-site disposal of waste according to the laboratory characterization. If the wastes are determined to be hazardous wastes, the Contractor shall also prepare manifests, as necessary.

3.11 SUMMARY REPORT

Following monitoring well installation, the Contractor shall prepare a summary report describing site activities, survey data of the well locations, and investigation-derived waste disposal.

END OF SECTION

SECTION 02100

INJECTION WELL INSTALLATION

PART 1 GENERAL

1.1 SUMMARY

The Contractor shall furnish labor, materials, and equipment to install the horizontal potassium permanganate injection wells described herein. The horizontal well locations are shown on Drawing C-2 and the well construction details are shown on Drawing C-3 and C-4 (Appendix A).

1.2 SUBMITTALS

A. Injection well permits.

B. Proof of State license to perform Work covered by this Section.

C. Drilling fluid manufacturer's specifications.

D. Summary report at the completion of installation.

1.3 QUALITY ASSURANCE

A. Perform Contract Work in accordance with the plans and specifications. The Engineer will be on site during drilling operations.

1. Upon request, provide information to the Engineer regarding actual locations of horizontal injection wells, depths, well construction details, and drilling difficulties encountered.
2. Submit signed copy of driller's logbook statements for monitoring well permits.

PART 2 PRODUCTS

2.1 MATERIALS

A. Well blank casing: 1-inch nominal diameter, SDR-11, HDPE.

B. Well perforated interval: 1-inch diameter, HDPE, perforated in the field with 1/8-inch-diameter holes on 15-foot centers.

C. Carrier casing: Sized for the protection of three 1-inch well perforated intervals to be removed after well development.

D. Filter Fabric: Mirafi 140N or equivalent, wrapped around the well perforated interval to keep silt from entering the well.

E. Drilling Fluid: A commercially available biodegradable, clay-free drilling fluid, easily broken down chemically using a concentrated powdered enzyme. Prior to drilling, the Contractor shall submit the drilling fluid manufacturer's specifications to the Owner for approval.

F. Bentonite Grout: A commercially available bentonite grout mixture developed for environmental monitoring well applications shall be used where indicated. The bentonite grout mixture shall be prepared according to manufacturer's instructions for installation by tremie pipe.

G. Miscellaneous fittings: 1-inch diameter, HDPE as indicated.

H. Surface Completion: Flush-mounted, traffic-rated well box secured with mortar collars and concrete pads that are flush with the ground surface. Stainless steel bolts will be used on all well covers installed on the flight apron.

PART 3 EXECUTION

3.1 INJECTION WELL LOCATIONS

The injection wells will be located within the Shallow Zone treatment area as shown on Drawing C-2 (Appendix A). The well entrances and exits will be in areas undisruptive to the flight apron and building operations. The well perforated intervals and perforated pipe lengths will be at a depth of 21 feet within a 10-foot radius of the following survey coordinates:

Well Location	Perforation Easting	Interval Northing	Total Perforated Length	Length of Each Perforated Pipe
Well A	7667417.61 7667140.92	704413.91 704405.73	276	92
Well B	7667462.34 7667070.23	704333.84 704337.57	393	131
Well C	7667457.60 7667036.42	704264.84 704282.54	423	141
Well D	7667403.59 7667026.47	704190.69 704228.37	381	127

It is possible that these locations may change based on the results of the groundwater samples collected and analyzed during monitoring well installation. This data will be used in the final determination of the horizontal injection well locations.

3.2 PERMIT REQUIREMENTS

The installation of groundwater injection wells will require submittal of a Start Card – Notice of Beginning of Well Construction by the drilling Subcontractor to the Oregon Water Resources Department, prior to installing wells. The injection locations require registration through the Oregon Underground Injection Control Program or Water Quality Program. The well registration materials will be submitted to the ODEQ in accordance with their requirements. If Portland ANGB is not required to obtain the appropriate permits, it will still be necessary to meet the substantive requirements associated with these permits. The substantive requirements, as communicated by the ODEQ to ANG personnel in a letter dated 2 August 2000, are as follows:

A. The injection locations must be registered with the ODEQ Underground Injection Control Program. Upon completion of injection activities, a proposal for proper decommissioning of injection locations will be submitted to the ODEQ.

B. The ANG will provide public notice (published in local newspapers and mailers sent to interested parties) and a 30-day opportunity to comment on the proposed injection activities. A public meeting must be held to receive comments, if requested by 10 or more persons, or by a group with a membership of 10 or more. Public notification is being satisfied through public review of this document.

C. No activities will be conducted that exacerbate existing groundwater contamination or that could cause an adverse impact on existing or potential beneficial uses of groundwater.

D. Activities will include an adequate monitoring and reporting program to allow the public to confirm that activities are not having an adverse impact.

E. Prior to expanding the scope of injection activities, the ANG will provide public notice and a 30-day opportunity to comment on the proposed expanded injection activities.

Work clearances are required by the Portland ANGB prior to drilling to ensure adequate precautions have been taken to protect underground utilities. Work clearance requests will be submitted for Portland ANGB approval prior to mobilizing the drilling Subcontractor to the site.

3.3 DRILLING ACTIVITIES

The southernmost injection well (Well D) will be installed first. This well will be used for the initial potassium permanganate injection described in Section 2.4.2 of the text. The wells shall be installed using the following guidelines:

A. Utilities in the vicinity of the drilling site shall be located prior to mobilization of the drilling Subcontractor to the Portland ANGB.

B. Any necessary excavation/boring permits shall be completed and submitted to the appropriate Portland ANGB personnel for approval.

1. In the event that drilling at any of the planned locations will interfere with subsurface utilities, the wells shall be relocated as close as possible to the original locations.

2. Relocated drilling locations shall be approved by the Portland ANGB Civil Engineer or designated representative.

3. Planned drilling locations shall be staked or painted in the field for inspection and approval by the Portland ANGB Civil Engineer.

C. The horizontal injection wells will be directionally drilled.

D. The wells will be drilled in three sections, the build section, the horizontal section, and the exit section, as shown on Drawing C-3 (Appendix A).

E. The well entry point will be a minimum of 110 feet from the desired start of the horizontal screen depth at the locations indicated on Drawing C-2 (Appendix A).

F. The well will be drilled at an angle of no greater than 25 degrees below horizontal to the desired depth of 21 feet.

G. The horizontal section will be drilled across the Shallow Zone treatment area, as shown on Drawing C-2 (Appendix A).

H. Once the desired horizontal length is achieved, the exit section will be drilled to the surface at a similar angle as the entrance section, exiting at a location undisruptive to the flight apron and building operations.

I. The borehole will then be reamed out to the desired diameter.

3.4 WELL INSTALLATION

The horizontal wells shall be completed as shown on Drawing C-3 (Appendix A) as follows:

A. The well casing will be constructed with three 1-inch pipes and placed in the carrier casing. The perforated interval will be wrapped with filter fabric prior to placement in the carrier casing.

B. The HDPE well casing material will be from continuous rolls, which will be fusion welded in the field to add length.

C. The carrier casing with the well casing will be pulled back through the borehole beginning at the exit section.

D. The build section will consist of blank casing.

E. The horizontal section will consist of three equal length perforated intervals across the treatment area (Drawing C-3 [Appendix A]).

F. Once the carrier casing and the well have been pulled through the borehole, the carrier casing will be filled with a concentrated powdered enzyme specifically designed to break down the drilling fluids.

G. The carrier casing will be removed from the borehole at the exit section while the break-down enzyme continues to be injected into the well. The total enzyme volume will be equal to twice the borehole volume adjacent to the perforated section.

H. The fluid will remain in the well for at least 8 hours. The well will then be pumped using a suction pump or an airlift pump. The pumped fluid parameters will be observed and recorded until the development criteria are met.

I. The exit section will be grouted to the surface. Post construction, complete the surface to match the existing grade.

J. The top 30 feet of casing in the build section will be grouted to the surface.

K. The top of the casing will be completed as shown on Drawing C-4 (Appendix A).

Alternative drilling and well installation methods, including blind drilling of the wells and installation without the use of carrier casing, may be used by the Contractor with prior approval by the Owner and Engineer.

3.5 BOREHOLE LOGGING

Execution same as described in Section 02000.

3.6 EQUIPMENT DECONTAMINATION

Execution same as described in Section 02000.

3.7 SURVEYING

A licensed surveyor will conduct surveying activities. The Contractor shall be responsible to provide an accurate location map of the entire length of the horizontal well, accurately displaying the underground location of the piping. Also the injection well head shall be surveyed both horizontally and vertically using existing control monuments at the Portland ANGB. The location of the top of the well casings will be established to the nearest ±0.01 foot vertically and to the nearest ±0.1 foot horizontally.

3.8 INVESTIGATION-DERIVED WASTE

Drill cuttings, well purge water, well development water, and equipment decontamination water shall be contained in temporary storage containers designated as hazardous/dangerous waste or nonhazardous/nondangerous waste, in accordance with Federal Resource Conservation and Recovery Act. The Contractor shall sample the wastes and submit the samples to a laboratory; disposal options shall be evaluated following laboratory characterization. The Contractor shall transport and dispose of the waste to the proper off-site location as determined by the laboratory characterization.

3.9 SUMMARY REPORT

Following injection well installation, the Contractor shall prepare a summary report describing site activities, survey data of the well locations, and investigation-derived waste disposal.

END OF SECTION

SECTION 02200

POTASSIUM PERMANGANATE SOLUTION INJECTION

PART 1 GENERAL

1.1 SUMMARY

The Contractor shall furnish labor, materials, tools, transportation, and supervision to inject potassium permanganate solution into the horizontal wells shown on Drawings C-2 and C-3 (Appendix A).

PART 2 PRODUCTS

2.1 POTASSIUM PERMANGANATE

The Material Safety Data Sheet for potassium permanganate is included in Appendix D.

2.2 PUMP PERFORMANCE REQUIREMENTS

The pump shall be capable of delivering 30 gallons per minute at 87 feet of water head (Appendix C).

2.3 INJECTION MANIFOLD

The Contractor shall prepare an injection manifold as shown on Drawing C-4 (Appendix A), including a minimum of the following:

A. A union to connect to each of the pipes from the well;

B. A globe valve on each pipe from the well; and

C. A totalizer to track the flow rates in each pipe.

PART 3 EXECUTION

3.1 INJECTION PREPARATION

Potassium permanganate shall be injected in accordance with Owner-approved Contractor's HSP (Section 01200). Based on the rationale presented in the text, potassium permanganate will be injected as a 2 percent, water-based solution in each injection well. Approximately 5 pounds of potassium permanganate will be mixed with approximately 30 gallons of City water per foot of injection well screen. Note that the actual injection volume may change with the results of the treatability test and the injection pilot test. The City water shall be provided by an on-site hydrant, as described in Section 01000. Prior to mixing, the City water shall be sampled and analyzed for chlorides. The permanganate solution shall be continuously mixed to prevent precipitation.

3.2 TREATABILITY TEST

During the monitoring well installation, a treatability test will be conducted to quantify the native soil demand for potassium permanganate. The treatability test will consist of the following:

A. Initial characterization: Approximately 1 kilogram of site soil and two, 1-liter bottles of representative site groundwater will be collected during monitoring well installation and sent to the laboratory conducting the treatability test.

B. Determination of Total Potassium Permanganate Demand: The tests will be performed by spiking similar slurry solutions with potassium permanganate at a series of concentrations allowing to react for 21-day test period. The concentrations will be selected to bracket the anticipated potassium permanganate demand of soil. At the conclusion of the reaction period, the concentration of unreacted potassium permanganate will be determined.

3.3 PILOT TEST PROCEDURES

A pilot test will be performed on the first completed injection well (the southernmost well). The potassium permanganate solution will be injected into this well at approximately 30 gallons per minute. Water levels and colorometric samples will be collected from the adjacent wells during the injection to monitor the injection effects. The results of this injection will determine the volume of potassium permanganate injected into the other wells.

3.4 INJECTION PROCEDURES

The potassium permanganate solution shall be pumped into the injection wells at approximately 30 gallons per minute until the total volume has been injected.

END OF SECTION

SECTION 02300

GROUNDWATER MONITORING

PART 1 GENERAL

1.1 SUMMARY

The Contractor shall furnish labor, materials, tools, and transportation to monitor the 13 Shallow Zone monitoring wells shown on Drawing C-2 (Appendix A). Groundwater monitoring activities shall be performed in accordance with the *Final 2001-2002 Groundwater Monitoring Work Plan*, dated July 2001.

PART 2 PRODUCTS – NOT USED

PART 3 EXECUTION

3.1 BACKGROUND SAMPLING

Prior to potassium permanganate injection, groundwater samples will be collected from the six existing (MW11-1, MW11-3, MW11-4, MW11-5, MW11-6 and MW11-13) and six new Shallow Zone monitoring wells. These samples will be used to obtain baseline data on reduction oxidation (redox) potential, concentrations of metals, dissolved oxygen, chloride ions, and concentrations of VOCs. The analyses to be performed during this test are detailed later in this section.

3.2 POST INJECTION SAMPLING

Following the first complete injection of potassium permanganate, the 13 Shallow Zone monitoring wells will be monitored quarterly for 2 years for contaminants of concern and monitored natural attenuation parameters.

3.3 SAMPLING PROCEDURES

Groundwater sampling shall be performed in accordance with the *Final 2001-2002 Groundwater Monitoring Work Plan*, dated July 2001. The Contractor shall sample the wells according to the following procedures:

A. The physical condition of monitoring wells will be documented during each monitoring event. Field personnel will inspect each well for maintenance and repair needs including the well seal, the vault seal, the well casing, and the well vault.

B. The monitoring wells will be ranked as to their potential degree of contamination, and those with the lowest potential will be sampled first each quarter.

C. Static water levels will be measured in all monitoring wells on a quarterly basis. Depth-to-water measurements will be recorded for all wells in a single day at the beginning of each sampling round. Water level measurements will be collected consistently from the north side of the well casing using an electronic water level indicator. Water level measurement and volume extraction data will be recorded in the field log book. These values will be used to calculate the required purge volume.

D. Purging of the monitoring wells will be performed using a submersible pump, a peristaltic pump, or a bladder pump in accordance with low-flow methodology. If sampling for natural attenuation parameters, a peristaltic pump or bladder pump with no metal parts will be used. A fresh length of disposable polyethylene (or equivalent) tubing will be attached to the pump. The pump will be lowered slowly into the wells to minimize the mixing of casing water. The pump will then be placed near the middle or slightly above the middle of the screened interval. The wells will be purged at 100 to 500 milliliters per minute. During the purging process, the specific conductivity, acidity/alkalinity (pH), turbidity, dissolved oxygen, redox potential, and temperature of the water will be measured and recorded in the field log book every 3 to 5 minutes. Purging will stop when the parameters have stabilized or when at least three well volumes have been purged. Stabilization parameters and associated permitted deviations include:

1. pH: +/- 0.1 unit

2. Temperature: +/- 1^{o} degree Celsius

3. Specific Conductivity: +/- 10 percent

4. Turbidity Goal: 5 Nephelometric Turbidity Unit

5. Dissolved Oxygen: 10 percent

6. Redox Potential: 10 percent

If continuous flow is lost during purging of low-yield wells, the well will be allowed to recover as much as possible within 24 hours and then will be sampled. Purge water will be containerized in 55-gallon drums and transported to a central storage area to be identified by 142nd FW personnel.

E. Once purging is completed and the measured parameters have stabilized, samples will be collected directly from the pump discharge in the following order: volatile natural attenuation samples first, chlorinated VOC samples second, and inorganic natural attenuation samples last. Dissolved hydrogen samples will be collected in accordance with the "bubble strip" method (USEPA, 1998). Dissolved inorganic samples will be filtered prior to collection in preserved sample containers. Care will be exercised to ensure no headspace exists in the samples. Occasionally, it may be difficult to eliminate air bubbles when sample containers have been pre-preserved. If air bubbles form, the sample and container will be discarded, and a new sample will be obtained in an identical container. This process will be repeated until no air bubbles are present.

F. Label, preserve, and place the samples on ice.

G. Ship the samples to the laboratory for chemical testing under chain-of-custody.

H. Contain, sample, and characterize purge water for subsequent disposal by the Contractor.

3.4 MONITORING

The monitoring wells will be monitored for the following:

A. Field parameters, including:

1. Groundwater level elevation
2. Redox potential
3. Dissolved oxygen
4. Specific conductance
5. Temperature
6. pH
7. Turbidity

B. Chemicals of concern:

1. Chlorinated VOCs using USEPA Test Method 8260B;

C. Monitored natural attenuation parameters including:

1. Dissolved chromium using USEPA Test Method 6010B;
2. Dissolved cadmium using USEPA Test Method 6010B;
3. Dissolved mercury using USEPA Test Method 7470A;
4. Dissolved iron using USEPA Test Method 6010B;
5. Dissolved manganese using USEPA Test Method 6010B;
6. Dissolved potassium using USEPA Test Method 6010B; and
7. Chloride ion using USEPA Test Method 300.0.

3.5 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance and quality control samples including trip blanks, rinsate blanks, field blanks, field duplicates, and matrix spike/matrix spike duplicates shall be collected during each quarterly sampling event.

3.6 PURGE WATER

Purge water from the monitoring wells will be contained in Department of Transportation-approved 55-gallon drums. The Contractor shall sample the wastes and submit the samples to a laboratory. The Contractor shall dispose of the drums following laboratory characterization.

3.7 SUMMARY REPORT

The Contractor shall prepare quarterly summary reports regarding site activities, laboratory sample results, and potassium permanganate injection effectiveness.

END OF SECTION

SECTION 02400

SOIL VAPOR EXTRACTION SYSTEM INSTALLATION

PART 1 GENERAL

1.1 SUMMARY

The Contractor shall furnish materials for and shall construct the SVE system in the location of the former oil/water separator as shown on Drawings C-5, C-6, and C-7 (Appendix A).

1.2 SUBMITTALS

A. Supply reproducible scaled drawings showing equipment and instrument plans and details, factory test results, performance curves, and wiring diagrams.

B. Supply operation and maintenance manuals for each instrument and piece of equipment.

1.3 QUALITY ASSURANCE

A. Provide equipment and instrument with nameplate identifying, at a minimum, manufacturer's name, model number, and rating/capacity.

1.4 ELECTRICITY REQUIREMENTS

The Contractor shall provide wiring from on-site power source to the SVE location.

PART 2 PRODUCTS

2.1 SVE PIPING

The Contractor shall connect the blower and GAC units to existing SVE piping. The existing SVE piping is two horizontal, 4-inch-diameter, Schedule 40 PVC pipes with alternating slotted screen and blank sections installed at approximately 5 feet below ground surface within the soil excavation during the 1999 soil removal action.

2.2 VAPOR MONITORING POINTS

The Contractor shall install eight, 1-inch VMPs in locations shown on Drawing C-5 (Appendix A). The construction details are shown on Drawing C-7 (Appendix A) and the materials are described below:

A. VMP Casing: 1-inch diameter, Schedule 40 PVC, threaded, flush joint, as indicated.

B. VMP Screen: 1-inch diameter, threaded, flush joint, Schedule 40 PVC screen, 0.020 slot, as indicated.

C. Bentonite Seal: Mixture of bentonite powder and potable water.

D. Filter pack: No. 5 quartz sand.

E. Cap: Watertight PVC threaded cap with a PVC sampling port drilled into the top.

F. Surface Completion: Below-grade, traffic-rated vaults secured with mortar collars and concrete pads that are flush with the ground surface. Stainless steel bolts will be used on all well covers installed on the flight apron.

2.3 VACUUM BLOWER

The Contractor shall supply and install a positive displacement-type blower with a flow rate of 50 standard cubic feet per minute at 6 inches of mercury vacuum powered by an electric motor.

2.4 GRANULAR ACTIVATED CARBON UNITS

The Contractor shall supply and install two, 200-pound GAC units.

2.5 MOISTURE RECOVERY DRUM

The Contractor shall supply and install a 55-gallon moisture recovery drum. A submersible electric sump pump equipped with a float switch shall be installed in the moisture recovery drum. The high level float switch shall activate the pump when the water is no higher than one third of the total drum height and deactivate the pump when the drum is empty. A high-high level switch, which shuts off the entire system, shall be installed 3 inches above the high level switch. The sump pump shall be connected through PVC piping to a 1,000-gallon polyethylene storage tank. The moisture recovery drum shall also have a valve at the bottom so the recovered water can be removed from the drum in case of pump failure.

2.6 WATER STORAGE TANK

The Contractor shall supply and install a 1,000-gallon closed polyethylene tank for water storage prior to disposal. The tank shall be equipped with a high level switch that shuts down the system when activated. The Contractor shall sample, characterize, and properly dispose of the water, as needed.

2.7 DISCHARGE STACK

The Contractor shall supply and install a discharge stack at a minimum of 10 feet above ground surface.

2.8 PIPING, FITTINGS, AND VALVES

The Contractor shall supply and install piping, fittings, hoses, and valves as shown on the drawings (Appendix A).

2.9 MISCELLANEOUS GAGES

The Contractor shall supply and install gages as shown in the drawings, including an hour meter to monitor system operation times, a temperature gage, a high sensitivity in-line air flow meter, pressure gages, and vacuum gages.

2.10 INSTRUMENTATION AND SWITCHES

A. General Requirements

1. Furnish necessary labor, materials, equipment, and incidentals required to install a complete and operational control system according to the intent of the drawings (Appendix A) and this specification.

2. The Contractor will be responsible for the mounting, wiring, calibration, testing, and checkout on control, monitoring, and safety instruments.

3. The Contractor shall test each instrument loop to ensure compatibility with the completed system. At the successful completion of each test, a green tag shall be attached to the active device.

B. System Controls

1. A high-high level shutoff switch shall be provided in the moisture recovery drum, which shuts down the blower when activated.

2. A high level shutoff switch shall also be provided in the water storage tank, which shuts down the blower when activated.

3. A high-pressure shutoff switch shall be installed on the blower.

4. A float switch shall be provided in the moisture recovery drum to control the pump.

PART 3 EXECUTION

3.1 GENERAL REQUIREMENT

Equipment and appurtenances shall be installed in the position indicated and in accordance with the manufacturer's written instructions. Appurtenances required for a complete and operating system shall be provided.

3.2 EQUIPMENT ANCHORING

Adequately anchor and support equipment to concrete apron using anchor bolts and steel channel or strut-type devices. In addition, vibratory pads shall be installed underneath the blower.

3.3 TESTING

A. Conduct pressure or leakage tests on newly installed pipelines. Furnish necessary equipment and materials and make taps in the pipe, as required. The Engineer will monitor testing.

B. Pipelines shall be tested in accordance with the manufacturer's recommendations and visually examined for leaks.

C. Pressure tests should be conducted at 30 pounds per square inch gage for 1 hour.

3.4 SYSTEM STARTUP

After the SVE system has been constructed, a baseline soil-gas survey using the PID, carbon dioxide (CO_2) and oxygen (O_2) meters will be performed at the VMPs. Following the survey, the SVE blower will be started, and after stable operation parameters have been attained, the SVE off-gases will be monitored with the PID and CO_2 meter at the influent stream and after the first and second GAC units. One vapor sample will be collected from both the influent and the effluent points. The samples will be collected in laboratory-provided summa canisters to be analyzed for VOCs using USEPA Method T0-15.

END OF SECTION

SECTION 02500

SOIL VAPOR EXTRACTION SYSTEM OPERATION AND MAINTENANCE

PART 1 GENERAL

1.1 SUMMARY

The Contractor shall furnish labor, materials, tools, and transportation to perform Work related to O&M of the SVE system. The SVE system shall be operated for 2 years, only during periods of low water table.

1.2 OPERATION AND MAINTENANCE MANUAL

A. The Contractor shall prepare an O&M Manual for the SVE treatment system O&M.

1. Submit draft manual for Owner's review and approval at least 2 weeks prior to startup.

2. Submit final manual for Owner's review and approval 10 days after startup and adjustment operation period.

B. The O&M Manual shall be subject to Owner's review and approval prior to acceptance.

1.3 REQUIREMENTS FOR PREPARATION OF OPERATION AND MAINTENANCE MANUAL

A. Contents: Prepare a Table of Contents for each volume, with each product or system description identified.

B. Part 1: Directory, listing names, addresses, and telephone numbers of Architect/Contracting Officer Representative, Contractor, Subcontractors, and major equipment suppliers.

C. Part 2: O&M instructions, arranged by system. For each category, identify names, addresses, and telephone numbers of Subcontractors and suppliers. The O&M Manual shall include the following:

1. Significant design criteria;

2. Operating instructions and procedures for each item of equipment;

3. Maintenance instructions for equipment and systems, including procedures for long-term shutdown;

4. Maintenance instructions for special finishes, including recommended cleaning methods and materials and special precautions identifying detrimental agents;

5. O&M requirements of all items.

6. SVE treatment system maintenance schedules for monthly and quarterly maintenance.

7. A complete set of as-built drawings for the Contract Work.

D. Part 3: Warranties, including the following:

1. Photocopies of manufacturers' warranties on equipment.

2. Executed and assembled documents from Subcontractors, suppliers, and manufacturers.

PART 2 PRODUCTS

2.1 OPERATION AND MAINTENANCE METERS

The Contractor shall supply a PID, a percent CO_2 meter, and vacuum gage(s) for monthly O&M activities.

PART 3 EXECUTION

3.1 SYSTEM VISITS

The Contractor shall visit the system every 2 weeks during system operation to collect routine system measurements and perform maintenance activities. Routine system measurements shall include:

A. PID measurements from the influent vapor and VMPs to quantify the amount of volatiles present;

B. CO_2 concentrations from the influent vapor and VMPs to estimate the amount of enhanced biodegradation which is occurring in the subsurface. Because the petroleum hydrocarbons to be removed by the SVE system consist of several chemicals, dodecane will be used as the proxy chemical for purposes of mass estimation. The balanced equation for the degradation of dodecane to CO_2 and water is:

$$C_{12}H_{26} + 18.5\ O_2 = 12\ CO_2 + 13\ H_2O.$$

Therefore, 12 moles of CO_2 are utilized for every one mole of $C_{12}H_{26}$. In addition to this biological process, some CO_2 is generated from bicarbonate by the following chemical equation:

$$2(HCO_3\text{-}1) = CO_2 + H_2O$$

The CO_2 field reading will be corrected to account for the bicarbonate reaction by subtracting 2000 ppmv from the CO_2 reading. The mass removed due to biodegradation based on CO_2 production (m_{CON}) will be calculated as follows:

$$m_{CON} = Q * C_{CO2} * MCF * T * 1440 \text{ minutes/day}$$

where:

m_{CON} = Approximate contaminant mass biodegraded (pounds);

Q = Blower volumetric flow rate (standard cubic feet per minute);

C_{CO2} = Concentration of CO_2 (ppmv);

MCF = Molar conversion factor = (MW of dodecane)/385 x 10^6 (Source: EPA document AP-42, Volume I, Fifth Edition -- January 1995); and

T = Time operating (days).

C. Vacuum measurements at each VMP to determine the radius of influence of the SVE system; and

D. Flow, pressure, and temperature measurements collected from the gages on the SVE system.

Field measures shall be recorded in the project field log book. General maintenance of the SVE system includes the following:

A. Check the level and condition of the blower oil and replace if necessary.

B. Check the condition of the blower air filter and replace if necessary.

C. Check the moisture level in the moisture recovery drum and transfer collected water to 55-gallon drums if necessary.

D. Check piping, valves, and gages for proper working condition.

E. Change the spent carbon in the GAC units.

3.2 SOIL VAPOR EXTRACTION SYSTEM SAMPLES

The Contractor shall collect monthly vapor samples from the influent and effluent of the GAC units. The samples shall be collected in laboratory-provided summa canisters to be analyzed for VOCs using USEPA Method TO-15. The Contractor shall also collect any other vapor samples required to assess the system performance.

The Contractor will evaluate results of laboratory analyses performed on samples to determine if SVE treatment system is operating as specified and in accordance with performance requirements and applicable local laws. Contractor shall adjust SVE system O&M as directed by the Engineer and as indicated by results of laboratory analyses performed on samples.

3.3 SUMMARY REPORTS

The Contractor shall prepare quarterly summary reports describing site activities, monthly laboratory sample results, operation and maintenance system readings, and mass removal rates.

END OF SECTION

SECTION 02600

ORC INJECTION

PART 1 GENERAL

1.1 SUMMARY

The Contractor shall furnish labor, materials, tools, transportation, and supervision to inject ORC into the area surrounding the former oil/water separator, as described herein. ORC injections shall be performed during high water table conditions. The ORC injection locations are shown on Drawing C-5 (Appendix A).

PART 2 PRODUCTS

2.1 OXYGEN-RELEASING COMPOUND

The Contractor shall purchase the ORC. The Material Safety Data Sheet for ORC is included in Appendix D.

PART 3 EXECUTION

3.1 INJECTION PREPARATION

Approximately 15 pounds of ORC mixed with 4.2 gallons of water will be injected into each injection point. The ORC slurry will be continually mixed using a heavy-duty power mixer in a 55-gallon plastic tank. The use of the 55-gallon tank will allow for enough slurry to be mixed for approximately three to four injection points at a time, while not allowing it time to harden and become unusable. A paddle, in addition to the heavy-duty power mixer, will be used to scrape the bottom and sides of the tank to ensure complete mixing of the slurry prior to injection.

3.2 INJECTION PROCEDURES

The Contractor shall inject ORC using a standard GeoProbe™ (direct push) drill rig. An Oregon State-certified well driller will be contracted to perform ORC injection, as summarized below:

A. Prior to injection, the water level will be taken at Shallow Zone monitoring well MW11-3.

B. At each ORC injection point, a 1-inch rod will be advanced to an approximate depth of 12 feet (using standard GeoProbe™ procedures).

C. A high-pressure slurry pump will be connected to the 1-inch rod and while slowly withdrawing the rod from the borehole, the slurry will be pumped into the aquifer.

D. Once the top of the capillary fringe/smear zone is reached, a bentonite seal will be filled to the top of the borehole. The ground surface will then be restored to its original condition.

E. Downhole equipment will be decontaminated prior to use.

F. Soil cuttings and decontamination water shall be contained and sampled at the conclusion of the ORC injection. The waste shall be disposed of properly following characterization.

END OF SECTION

APPENDIX C

DESIGN CALCULATIONS

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Project PANG Site 11 95% Design | Project No. ______ | Sheet 1 of 1
Subject $KMnO_4$ Mass requirement | By Heather Lee | Date 7/11/01
| Chkd. by ______ | Date ______

Purpose: Determine required mass of $KMnO_4$ required to degrade vinyl chloride.

Method: Equation Mass balance

Assumptions:

$$\underline{10}\, KMnO_4 + \underline{3}\, C_2H_3Cl \longrightarrow \underline{6}\, CO_2 + \underline{10}\, MnO_4 + \underline{10}\, K^+ + \underline{3}\, Cl^- + \underline{7}\, OH^- + \underline{\ }\, H_2O$$

Calculations:

molar ratio of $\dfrac{KMnO_4}{C_2H_3Cl} = \dfrac{10}{3}$

Molecular weight $KMnO_4 = 39.1 + 54.94 + 4(16)$
$= 158.04\ g/gmol$

Molecular weight $C_2H_3Cl = 2(12) + 3(1) + 35$
$= 62\ g/gmol$

$\therefore$ mass ratio $\dfrac{KMnO_4}{C_2H_3Cl} = \dfrac{10 \times 158.04}{3 \times 62}$

$$= \boxed{8.5\ \dfrac{g\ KMnO_4}{g\ C_2H_3Cl}}$$

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Project Portland ANG 95% Design — Project No. 6101 — Sheet 1 of 2
Subject Calculate Permanganate Mass — By CLB — Date 6/12/01
Chkd. by ______ Date ______

Goal: Calculate mass of Potassium Permanganate Required and Volume of Solution to Inject.

Basis: Use 500 µg/L Vinyl chloride as contaminant
8.5 is ratio of potassium permanganate required per unit of Vinyl Chloride
Effective Porosity of Shallow Zone is 0.25
Treatment Area for each injection well is 75' wide by 10' deep.

Mass of Potassium Permanganate:

$$\frac{500\ \mu g\ \text{Vinyl chloride}}{L\ \text{Groundwater}} \times \frac{0.25\ L\ \text{groundwater}}{L\ \text{bulk}} \times \frac{8.5\ \mu g\ KMnO_4}{\mu g\ \text{Vinyl Chloride}}$$

$$\times \frac{10^{-6}\ g}{\mu g} \times \frac{0.002205\ lb}{g} \times \frac{28.32\ L}{ft^3} = 6.63E\text{-}5\ \frac{lb\ KMnO_4}{ft^3}$$

Volume treated per unit foot of injection well is $1' \times 75' \times 10' = 750\ ft^3$

Mass of $KMnO_4$ per unit foot of injection well

$$750\ ft^3 \times 6.63E\text{-}5\ \frac{lb\ KMnO_4}{ft^3} = 0.05\ lb\ KMnO_4$$

$0.05\ \frac{lb\ KMnO_4}{ft\ \text{screen}}$ is purely based on stoichiometric demand of 500 µg/L Vinyl chloride.

more →

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Project ______ Project No. 6101 Sheet 2 of 2
Subject $KMnO_4$ Volume/Mass By CLB Date ______
Chkd. by ______ Date ______

Soil Demand of $KMnO_4$ —

Assume 1g/Kg or 0.1% organic carbon in soil

$$0.001 \frac{\text{lb organic material}}{\text{lb soil}} \times \frac{\sim 65 \text{ lb soil}}{ft^3} \times 750\ ft^3 = 49\ \text{lb} \frac{\text{organic}}{\text{ft of well}}$$

Assume 5% destruction of native organic matter due to slow reaction of complex humic matter and a one-to-one usage of $KMnO_4$ (one pound $KMnO_4$ per pound organic destroyed)

$$49\ \text{lb} \frac{\text{organics}}{\text{ft of well}} \times 0.05 \times \frac{1\ \text{lb}\ KMnO_4}{\text{lb organic}} = 2.45\ \text{lb} \frac{KMnO_4}{\text{ft of well}}$$

Use 2.45 lb $KMnO_4$ plus 0.05 lb $KMnO_4$ from previous page.
Total = 2.5 lb $KMnO_4$ per foot of well.

Use 2% solution

$$\frac{2.5\ \text{lb}\ KMnO_4}{0.02} = 125\ \text{lb of solution at 2\% } KMnO_4$$

$$125\ \text{lb solution} \times \frac{1\ \text{gallon}}{8.3\ \text{lb}} = 15 \text{ gallons of solution per foot of well}$$

Use a safety factor of 2 to get 30 $\frac{\text{gallons}}{\text{foot of well}}$

Approximately 1400 feet of screened injection well
∴ Total volume ≅ 1400' × 30 gallons/ft = 42,000 gallons

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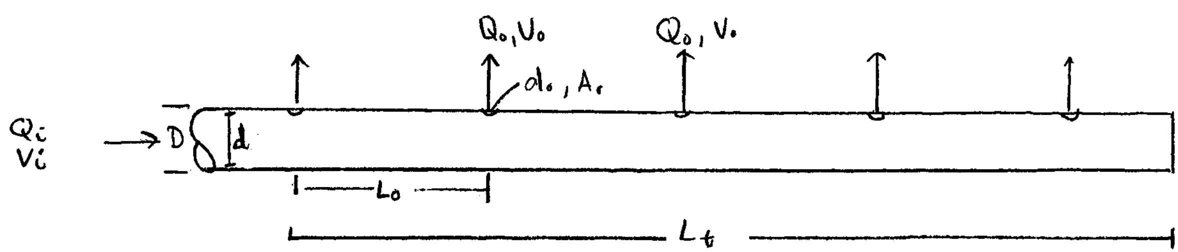
Project PANG Horizontal Well Screen Design Project No. 6101.52 Sheet 1 of 4
Subject ______ By Heather Lee Date 9/6/01
Chkd. by ______ Date ______

Purpose: Determine Horizontal well screen design (hole size and spacing).

Method: Pressure drop across holes needs to be much greater than the pressure drop across the length of pipe for uniform distribution.
Divide the total screened area into three equal length sections.

Assumptions:
Diameter of the holes is constant
Spacing of the holes is constant
Constant friction factor accross screen.
Smooth pipe



$Q_i = 10$ gpm
$D = 1.1$ in
$d = 1.033$ in
$L_T = 150$ ft
$L_o = 15$ ft
$d_o = 1/8$ in

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Project PANG Horizontal Well Screen Design Project No. 6101.52 Sheet 2 of 4
Subject By Heather Lee Date 9/6/01
Chkd. by Date

Total initial pipe flow rate, Q_i

$$Q_i = 10 \text{ gpm}$$
$$= 10 \frac{\text{gal}}{\text{min}} \times \frac{1 \text{ min}}{60 \text{ s}} \times \frac{1 \text{ m}^3}{264.17 \text{ gal}}$$
$$= 6.31 \times 10^{-4} \text{ m}^3/\text{s}$$

Inside Diameter, d

$$d = 1.033 \text{ in}$$
$$= 1.033 \text{ in} \times \frac{0.0254 \text{ m}}{\text{in}}$$
$$= 2.62 \times 10^{-2} \text{ m}$$

Cross Sectional Area of pipe (based on internal diameter), A

$$A = \frac{\pi}{4} d^2$$
$$= \frac{\pi}{4} (2.62 \times 10^{-2})^2$$
$$= 5.4 \times 10^{-4} \text{ m}^2$$

Initial velocity in pipe, V_i

$$V_i = \frac{Q_i}{A}$$
$$= \frac{6.31 \times 10^{-4} \text{ m}^3/\text{s}}{5.4 \times 10^{-4} \text{ m}^2}$$
$$= 1.17 \text{ m/s}$$

Total Length of pipe, L_T

$$L_T = 150 \text{ ft}$$
$$= 150 \text{ ft} \times \frac{0.3048 \text{ m}}{\text{ft}}$$
$$= 45.7 \text{ m}$$

Length between holes, L_o

$$L_o = 15 \text{ ft}$$
$$= 15 \text{ ft} \times \frac{0.3048 \text{ m}}{\text{ft}}$$
$$= 4.57 \text{ m}$$

Number of holes, X

$$X = \frac{L_T}{L_o}$$
$$X = \frac{45.7 \text{ m}}{4.57 \text{ m}}$$
$$= 10$$

Flow rate at each hole, Q_o

$$Q_o = \frac{Q_i}{X}$$
$$= \frac{6.31 \times 10^{-4} \text{ m}^3/\text{s}}{10}$$
$$= 6.31 \times 10^{-5} \text{ m}^3/\text{s}$$

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Project PANG Horizontal Well Screen Design Project No. 610152 Sheet 3 of 4
Subject ______ By Heather Lee Date 9/6/01
Chkd. by ______ Date ______

Diameter of holes, d_o

$$d_o = 1/8 \text{ in}$$
$$= 1/8 \text{ in} \times \frac{0.0254 \text{ m}}{\text{in}}$$
$$= 3.18 \times 10^{-3} \text{ m}$$

Area of hole, A_o

$$A_o = \frac{\pi}{4}(3.18 \times 10^{-3})^2$$
$$= 7.9 \times 10^{-6}$$

Velocity at each hole, V_o

$$V_o = \frac{Q_o}{A_o}$$
$$= \frac{6.31 \times 10^{-5} \text{ m}^3/\text{s}}{7.9 \times 10^{-6}}$$
$$= 7.97 \text{ m/s}$$

Reynold's number at the beginning of the screen, Re_i

$$Re_i = \frac{d V_i \rho}{\mu}$$ where $\rho = 1000 \text{ kg/m}^3$, $\mu = 0.001 \text{ Pa·s}$

$$= \frac{(2.62 \times 10^{-2})(1.17)(1000)}{0.001}$$
$$= 3.06 \times 10^4$$

Reynold's number at end of screen, Re_T

$$Re_T = \frac{d \frac{V_i}{x} \rho}{\mu}$$
$$= \frac{(2.62 \times 10^{-2})(\frac{1.17}{10}) 1000}{0.001}$$
$$= 3.06 \times 10^3$$

Friction factor at the beginning of screen, f_i

$$f_i = \frac{0.079}{Re^{0.25}}$$ for Turbulent flow in smooth pipes and $4000 < Re < 10^5$

$$f_i = \frac{0.079}{(3.06 \times 10^4)^{0.25}}$$
$$f_i = 0.006$$

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Friction factor at the end of the screen, f_T

$f_T = 0.011$ for smooth pipe using the Fanning Friction factor diagram

$f = \frac{16}{Re}$ in laminar region $Re < 2{,}100$

Average friction factor across screen, f

$$f = \frac{f_i + f_T}{2}$$

$$f = \frac{0.006 + 0.011}{2}$$

$$f = 0.0085$$

Net Pressure drop over length of distributor $= \Delta p$

$$\Delta p = \left(\frac{4 f L_T}{3 D} - 2K\right) \frac{\rho V_i^2}{2}$$

From Perry's Handbook for Chemical Engineers.

where $K = 0.5$ negligible viscous losses in portion of flow which remains

f = Fanning Friction factor

$$\Delta p = \left[\frac{4(0.0085)(45.7\,m)}{3(2.62 \times 10^{-2}\,m)} - 2(0.5)\right] \frac{1000\,(1.17)^2}{2}$$

$$\Delta p = 1.28 \times 10^4 \text{ Pa}$$

Pressure drop across holes, Δp_o

From Perry's Handbook for Chemical Engineers

$$\Delta p_o = \frac{1}{C_o^2} \frac{\rho V_o^2}{2}$$

where C_o = discharge coefficient typically 0.62

$$\Delta p_o = \frac{1}{(0.62)^2} \frac{1000\,\text{kg/m}^3\,(7.97\,\text{m/s})^2}{2}$$

$$\Delta p_o = 8.26 \times 10^4 \text{ Pa}$$

Percent Maldistribution, M

$$M = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p|}{\Delta p_o}}\right)$$

$$M = 100\left(1 - \sqrt{\frac{8.26 \times 10^4 - 1.28 \times 10^4}{8.26 \times 10^4}}\right)$$

$$M = 8\%$$

Well D Design Spreadsheet - Three ___ Foot Pipes
In Situ Treatment of Impacted Groundwater and Soil at IRP Site 11
Portland Air National Guard
Portland International Airport
Portland, Oregon

		English Units			Metric Units	
Flow Rate at beginning of perforated interval	Q_i	10	gpm		6.31E-04	m3/s
inside diameter of pipe	d	1.05	in		2.67E-02	m
Total length of perforated interval of pipe	L_t	127	ft		3.87E+01	m
Length between holes	L_o	15	ft		4.57E+00	m
Hole diameter	d_o	0.125	in		3.18E-03	m
K factor	K	0.5			0.5	
Discharge Coeficient	C_o	0.62			0.62	
Density of water					1000	kg/m3
Dynamic Viscosity of water					0.001	Pa*s
Number of Holes	X	9			9	
Inside area of pipe	A	6.01E-03	ft2		5.59E-04	m2
Velocity at the beginning of perforated interval	V_i	3.70E+00	ft/s		1.13E+00	m/s
Area of Hole	A_o	8.52E-05	ft2		7.92E-06	m2
Flow rate at each hole	Q_o	1.06E+00	gpm		6.66E-05	m3/s
Velocity at each hole	V_o	2.76E+01	ft/s		8.42E+00	m/s
Reynolds number at beginning of perforated interval	Re_i	3.01E+04			3.01E+04	
Reynolds number at end of perforated interval	Re_t	3.18E+03			3.18E+03	
friction factor at the beginning of perforated interval	f_i	6.00E-03			6.00E-03	
friction factor at the end of perforated interval	f_t	1.10E-02			1.10E-02	
average friction factor across perforated interval	f	8.50E-03			8.50E-03	
Net pressure drop over length of perforated interval	Δp	1.4	psi		9850	Pa
Pressure drop across holes	Δp_o	13.4	psi		92166	Pa
Percent Maldistribution	M	5	%		5	%

Well C Design Spreadsheet - Three ___ Foot Pipes
In Situ Treatment of Impacted Groundwater and Soil at IRP Site 11
Portland Air National Guard
Portland International Airport
Portland, Oregon

		English Units			Metric Units	
Flow Rate at beginning of perforated interval	Q_i	10	gpm		6.31E-04	m3/s
inside diameter of pipe	d	1.05	in		2.67E-02	m
Total length of perforated interval of pipe	L_t	141	ft		4.30E+01	m
Length between holes	L_o	15	ft		4.57E+00	m
Hole diameter	d_o	0.125	in		3.18E-03	m
K factor	K	0.5			0.5	
Discharge Coeficient	C_o	0.62			0.62	
Density of water					1000	kg/m3
Dynamic Viscosity of water					0.001	Pa*s
Number of Holes	X	10			10	
Inside area of pipe	A	6.01E-03	ft2		5.59E-04	m2
Velocity at the beginning of perforated interval	V_i	3.70E+00	ft/s		1.13E+00	m/s
Area of Hole	A_o	8.52E-05	ft2		7.92E-06	m2
Flow rate at each hole	Q_o	9.62E-01	gpm		6.07E-05	m3/s
Velocity at each hole	V_o	2.51E+01	ft/s		7.66E+00	m/s
Reynolds number at beginning of perforated interval	Re_i	3.01E+04			3.01E+04	
Reynolds number at end of perforated interval	Re_t	2.90E+03			2.90E+03	
friction factor at the beginning of perforated interval	f_i	6.00E-03			6.00E-03	
friction factor at the end of perforated interval	f_t	1.10E-02			1.10E-02	
average friction factor across perforated interval	f	8.50E-03			8.50E-03	
Net pressure drop over length of perforated interval	Δp	1.6	psi		11007	Pa
Pressure drop across holes	Δp_o	11.1	psi		76365	Pa
Percent Maldistribution	M	7	%		7	%

Well B Design Spreadsheet - Three ____ Foot Pipes
In Situ Treatment of Impacted Groundwater and Soil at IRP Site 11
Portland Air National Guard
Portland International Airport
Portland, Oregon

		English Units			Metric Units	
Flow Rate at beginning of perforated interval	Q_i	10	gpm		6.31E-04	m3/s
inside diameter of pipe	d	1.05	in		2.67E-02	m
Total length of perforated interval of pipe	L_t	131	ft		3.99E+01	m
Length between holes	L_o	15	ft		4.57E+00	m
Hole diameter	d_o	0.125	in		3.18E-03	m
K factor	K	0.5			0.5	
Discharge Coeficient	C_o	0.62			0.62	
Density of water					1000	kg/m3
Dynamic Viscosity of water					0.001	Pa*s
Number of Holes	X	10			10	
Inside area of pipe	A	6.01E-03	ft2		5.59E-04	m2
Velocity at the beginning of perforated interval	V_i	3.70E+00	ft/s		1.13E+00	m/s
Area of Hole	A_o	8.52E-05	ft2		7.92E-06	m2
Flow rate at each hole	Q_o	1.03E+00	gpm		6.48E-05	m3/s
Velocity at each hole	V_o	2.69E+01	ft/s		8.19E+00	m/s
Reynolds number at beginning of perforated interval	Re_i	3.01E+04			3.01E+04	
Reynolds number at end of perforated interval	Re_t	3.09E+03			3.09E+03	
friction factor at the beginning of perforated interval	f_i	6.00E-03			6.00E-03	
friction factor at the end of perforated interval	f_t	1.10E-02			1.10E-02	
average friction factor across perforated interval	f	8.50E-03			8.50E-03	
Net pressure drop over length of perforated interval	Δp	1.5	psi		10181	Pa
Pressure drop across holes	Δp_o	12.6	psi		87185	Pa
Percent Maldistribution	M	6	%		6	%

Well A Design Spreadsheet - Three ___ Foot Pipes
In Situ Treatment of Impacted Groundwater and Soil at IRP Site 11
Portland Air National Guard
Portland International Airport
Portland, Oregon

		English Units			Metric Units	
Flow Rate at beginning of perforated interval	Q_i	10	gpm		6.31E-04	m3/s
inside diameter of pipe	d	1.05	in		2.67E-02	m
Total length of perforated interval of pipe	L_t	92	ft		2.80E+01	m
Length between holes	L_o	15	ft		4.57E+00	m
Hole diameter	d_o	0.125	in		3.18E-03	m
K factor	K	0.5			0.5	
Discharge Coeficient	C_o	0.62			0.62	
Density of water					1000	kg/m3
Dynamic Viscosity of water					0.001	Pa*s
Number of Holes	X	7			7	
Inside area of pipe	A	6.01E-03	ft2		5.59E-04	m2
Velocity at the beginning of perforated interval	V_i	3.70E+00	ft/s		1.13E+00	m/s
Area of Hole	A_o	8.52E-05	ft2		7.92E-06	m2
Flow rate at each hole	Q_o	1.40E+00	gpm		8.84E-05	m3/s
Velocity at each hole	V_o	3.66E+01	ft/s		1.12E+01	m/s
Reynolds number at beginning of perforated interval	Re_i	3.01E+04			3.01E+04	
Reynolds number at end of perforated interval	Re_t	4.22E+03			4.22E+03	
friction factor at the beginning of perforated interval	f_i	6.00E-03			6.00E-03	
friction factor at the end of perforated interval	f_t	1.10E-02			1.10E-02	
average friction factor across perforated interval	f	8.50E-03			8.50E-03	
Net pressure drop over length of perforated interval	Δp	1.0	psi		6960	Pa
Pressure drop across holes	Δp_o	23.5	psi		162322	Pa
Percent Maldistribution	M	2	%		2	%

FLUID DISTRIBUTION

Uniform fluid distribution is essential for efficient operation of chemical-processing equipment such as contactors, reactors, mixers, burners, heat exchangers, extrusion dies, and textile-spinning chimneys. To obtain optimum distribution, proper consideration must be given to flow behavior in the distributor, flow conditions upstream and downstream of the distributor, and the distribution requirements of the equipment. Even though the principles of fluid distribution have been well developed for more than three decades, they are frequently overlooked by equipment designers, and a significant fraction of process equipment needlessly suffers from maldistribution. In this subsection, guides for the design of various types of fluid distributors, taking into account only the flow behavior within the distributor, are given.

Perforated-Pipe Distributors The simple perforated pipe or sparger (Fig. 6-34) is a common type of distributor. As shown, the flow distribution is uniform; this is the case in which pressure recovery due to kinetic energy or momentum changes, frictional pressure drop along the length of the pipe, and pressure drop across the outlet holes have been properly considered. In typical turbulent flow applications, inertial effects associated with velocity changes may dominate frictional losses in determining the pressure distribution along the pipe, unless the length between orifices is large. Application of the momentum or mechanical energy equations in such a case shows that the pressure inside the pipe increases with distance from the entrance of the pipe. If the outlet holes are uniform in size and spacing, the discharge flow will be biased toward the closed end. Disturbances upstream of the distributor, such as pipe bends, may increase or decrease the flow to the holes at the beginning of the distributor. When frictional pressure drop dominates the inertial pressure recovery, the distribution is biased toward the feed end of the distributor.

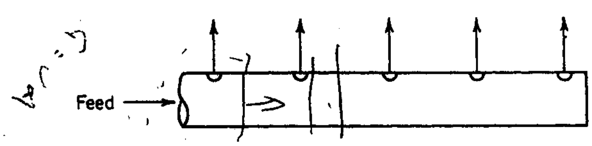


FIG. 6-34 Perforated-pipe distributor.

For turbulent flow, with roughly uniform distribution, assuming a constant friction factor, the combined effect of friction and inertial (momentum) pressure recovery is given by

$$\Delta p = \left(\frac{4fL}{3D} - 2K\right)\frac{\rho V_i^2}{2} \quad \text{(discharge manifolds)} \qquad (6\text{-}147)$$

where Δp = net pressure drop over the length of the distributor
L = pipe length
D = pipe diameter
f = Fanning friction factor
V_i = distributor inlet velocity

The factor K would be 1 in the case of full momentum recovery, or 0.5 in the case of negligible viscous losses in the portion of flow which remains in the pipe after the flow divides at a takeoff point (Denn, pp. 126–127). Experimental data (Van der Hegge Zijnen, *Appl. Sci. Res.*, **A3,** 144–162 [1951–1953]; and Bailey, *J. Mech. Eng. Sci.*, **17,** 338–347 [1975]), while scattered, show that K is probably close to 0.5 for discharge manifolds. For inertially dominated flows, Δp will be negative. For **return manifolds** the recovery factor K is close to 1.0, and the pressure drop between the first hole and the exit is given by

$$\Delta p = \left(\frac{4fL}{3D} + 2K\right)\frac{\rho V_e^2}{2} \quad \text{(return manifolds)} \qquad (6\text{-}148)$$

where V_e is the pipe exit velocity.

One means to obtain a desired uniform distribution is to make the average pressure drop across the holes Δp_o large compared to the pressure variation over the length of pipe Δp. Then, the relative variation in pressure drop across the various holes will be small, and so will be the variation in flow. When the area of an individual hole is small compared to the cross-sectional area of the pipe, hole pre drop may be expressed in terms of the discharge coefficient C the velocity across the hole V_o as

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2} \qquad (6$$

Provided C_o is the same for all the holes, the *percent maldistrib* defined as the percentage variation in flow between the first an holes, may be estimated reasonably well for small maldistributi (Senecal, *Ind. Eng. Chem.*, **49,** 993–997 [1957])

$$\text{Percent maldistribution} = 100\left(1 - \sqrt{\frac{\Delta p_o - |\Delta p|}{\Delta p_o}}\right) \qquad (6$$

This equation shows that for 5 percent maldistribution, the pr drop across the holes should be about 10 times the pressure dro the length of the pipe. For discharge manifolds with K = 0.5 (6-147), and with $4fL/3D$ << 1, the pressure drop across the should be 10 times the inlet velocity head, $\rho V_i^2/2$ for 5 percent n tribution. This leads to a simple design equation.

Discharge manifolds, $4fL/3D$ << 1, 5% maldistribution:

$$\frac{V_o}{V_i} = \frac{A_p}{A_o} = \sqrt{10}C_o \qquad ($$

Here A_p = pipe cross-sectional area and A_o is the *total* hole area distributor. Use of large hole velocity to pipe velocity ratios prc perpendicular discharge streams. In practice, there are many where the $4fL/3D$ term will be less than unity but not close t In such cases, Eq. (6-151) will be conservative, while Eqs. ((6-149), and (6-150) will give more accurate design calculati cases where $4fL/(3D) > 2$, friction effects are large enough to Eq. (6-151) nonconservative. When significant variations in the length of the distributor occur, calculations should be m dividing the distributor into small enough sections that constan be assumed over each section.

For return manifolds with K = 1.0 and $4fL/(3D)$ << 1, 5 maldistribution is achieved when hole pressure drop is 20 tir pipe exit velocity head.

Return manifolds, $4fL/3D$ << 1, 5% maldistribution:

$$\frac{V_o}{V_e} = \frac{A_p}{A_o} = \sqrt{20}C_o$$

When $4fL/3D$ is not negligible, Eq. (6-152) is not conservat Eqs. (6-148), (6-149), and (6-150) should be used.

One common misconception is that good distribution is alw vided by high pressure drop, so that increasing flow rate imprc tribution by increasing pressure drop. Conversely, it is mi believed that turndown of flow through a perforated pipe d using Eqs. (6-151) and (6-152) will cause maldistribution. H when the distribution is nearly uniform, decreasing the fl decreases Δp and Δp_o in the same proportion, and Eqs. (6-1 (6-152) are still satisfied, preserving good distribution indepe flow rate, as long as friction losses remain small compared tc (velocity head change) effects. Conversely, increasing the f through a distributor with severe maldistribution will not g produce good distribution.

Often, the pressure drop required for design flow rate is u ably large for a distributor pipe designed for uniform velocity uniformly sized and spaced orifices. Several measures may be such situations. These include the following:

1. Taper the diameter of the distributor pipe so that velocity and velocity head remain constant along the pipe, t stantially reducing pressure variation in the pipe.
2. Vary the hole size and/or the spacing between holes pensate for the pressure variation along the pipe. This metho sensitive to flow rate and a distributor optimized for one flow suffer increased maldistribution as flow rate deviates from de
3. Feed or withdraw from both ends, reducing the p velocity head and required hole pressure drop by a factor of

The orifice discharge coefficient C_o is usually taken to be about 0.62. However, C_o is dependent on the ratio of hole diameter to pipe diameter, pipe wall thickness to hole diameter ratio, and pipe velocity to hole velocity ratio. As long as all these are small, the coefficient 0.62 is generally adequate.

Example 9: Pipe Distributor A 3-in schedule 40 (inside diameter 7.793 cm) pipe is to be used as a distributor for a flow of 0.010 m³/s of water (ρ = 1,000 kg/m³, μ = 0.001 Pa · s). The pipe is 0.7 m long and is to have 10 holes of uniform diameter and spacing along the length of the pipe. The distributor is submerged. Calculate the required hole size to limit maldistribution to 5 percent, and estimate the pressure drop across the distributor.

The inlet velocity computed from $V_i = Q/A = 4Q/(\pi D^2)$ is 2.10 m/s, and the inlet Reynolds number is

$$\mathrm{Re} = \frac{DV_i\rho}{\mu} = \frac{0.07793 \times 2.10 \times 1000}{0.001} = 1.64 \times 10^5$$

For commercial pipe with roughness ϵ = 0.046 mm, the friction factor is about 0.0045. Approaching the last hole, the flow rate, velocity and Reynolds number are about one-tenth their inlet values. At Re = 16,400 the friction factor f is about 0.0070. Using an average value of f = 0.0057 over the length of the pipe, $4fL/D$ is 0.068 and may reasonably be neglected so that Eq. (6-151) may be used with C_o = 0.62,

$$\frac{V_o}{V_i} = \frac{A_p}{A_o} = \sqrt{10C_o} = \sqrt{10} \times 0.62 = 1.96$$

With pipe cross-sectional area A_p = 0.00477 m², the total hole area is 0.00477/1.96 = 0.00243 m². The area and diameter of each hole are then 0.00243/10 = 0.000243 m² and 1.76 cm. With V_o/V_i = 1.96, the hole velocity is 1.96 × 2.10 = 4.12 m/s and the pressure drop across the holes is obtained from Eq. (6-149):

$$\Delta p_o = \frac{1}{C_o^2}\frac{\rho V_o^2}{2} = \frac{1}{0.62^2} \times \frac{1000(4.12)^2}{2} = 22{,}100 \text{ Pa}$$

Since the hole pressure drop is 10 times the pressure variation in the pipe, the total pressure drop from the inlet of the distributor may be taken as approximately 22,100 Pa.

Further detailed information on pipe distributors may be found in Senecal (*Ind. Eng. Chem.*, **49**, 993–997 [1957]). Much of the information on tapered manifold design has appeared in the pulp and paper literature (Spengos and Kaiser, *TAPPI*, **46**[3], 195–200 [1963]; Madeley, *Paper Technology*, **9**[1], 35–39 [1968]; Mardon, et al., *TAPPI*, **46**[3], 172–187 [1963]; Mardon, et al., *Pulp and Paper Magazine of Canada*, **72**[11], 76–81 [November 1971]; Trufitt, *TAPPI*, **58**[11], 144–145 [1975]).

Slot Distributors These are generally used in sheeting dies for extrusion of films and coatings and in air knives for control of thickness of a material applied to a moving sheet. A simple slotted pipe for turbulent flow conditions may give severe maldistribution because of nonuniform discharge velocity, but also because this type of design does not readily give perpendicular discharge (Koestel and Tuve, *Heat. Piping Air Cond.*, **20**[1], 153–157 [1948]; Senecal, *Ind. Eng. Chem.*, **49**, 993–997 [1957]; Koestel and Young, *Heat. Piping Air Cond.*, **23**[7], 111–115 [1951]). For slots in tapered ducts where the duct cross-sectional area decreases linearly to zero at the far end, the discharge angle will be constant along the length of the duct (Koestel and Young, ibid.). One way to ensure an almost perpendicular discharge is to have the ratio of the area of the slot to the cross-sectional area of the pipe equal to or less than 0.1. As in the case of perforated-pipe distributors, pressure variation within the slot manifold and pressure drop across the slot must be carefully considered.

In practice, the following methods may be used to keep the diameter of the pipe to a minimum consistent with good performance (Senecal, *Ind. Eng. Chem.*, **49**, 993–997 [1957]):

1. Feed from both ends.
2. Modify the cross-sectional design (Fig. 6-35); the slot is thus farther away from the influence of feed-stream velocity.
3. Increase pressure drop across the slot; this can be accomplished by lengthening the lips (Fig. 6-35).
4. Use screens (Fig. 6-35) to increase overall pressure drop across the slot.

Design considerations for air knives are discussed by Senecal (ibid.). Design procedures for extrusion dies when the flow is laminar,

(6-158)

dependent of
mitude of
batch

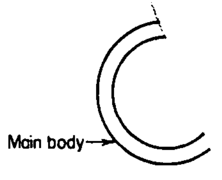


FIG. 6-35 Modified slot distributor.

as with highly viscous fluids, are presen ...g *of Thermoplastic Materials*, Rheinhold, pp. 248–281).

Turning Vanes In applications such a ...uation, the discharge profile from slots can be improved by turning vanes. The tapered duct is the most amenable for turning vanes because the discharge angle remains constant. One way of installing the vanes is shown in Fig. 6-36. The vanes should have a depth twice the spacing (*Heating, Ventilating, Air Conditioning Guide*, vol. 38, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1960, pp. 282–283) and a curvature at the upstream end of the vanes of a circular arc which is tangent to the discharge angle θ of a slot without vanes and perpendicular at the downstream or discharge end of the vanes (Koestel and Young, *Heat. Piping Air Cond.*, **23**[7], 111–115 [1951]). Angle θ can be estimated from

$$\cot\theta = \frac{C_d A_s}{A_d} \tag{6-153}$$

where A_s = slot area
A_d = duct cross-sectional area at upstream end
C_d = discharge coefficient of slot

Vanes may be used to improve velocity distribution and reduce frictional loss in bends, when the ratio of bend turning radius to pipe diameter is less than 1.0. For a miter bend with low-velocity flows, simple circular arcs (Fig. 6-37) can be used, and with high-velocity flows, vanes of special airfoil shapes are required. For additional details and references, see Ower and Pankhurst (*The Measurement of Air Flow*, Pergamon, New York, 1977, p. 102); Pankhurst and Holder (*Wind-Tunnel Technique*, Pitman, London, 1952, pp. 92–93); Rouse (*Engineering Hydraulics*, Wiley, New York, 1950, pp. 399–401); and Jorgensen (*Fan Engineering*, 7th ed., Buffalo Forge Co., Buffalo, 1970, pp. 111, 117, 118).

Perforated Plates and Screens A nonuniform velocity profile in turbulent flow through channels or process equipment can be smoothed out to any desired degree by adding sufficient uniform resistance, such as perforated plates or screens across the flow channel, as shown in Fig. 6-38. Stoker (*Ind. Eng. Chem.*, **38**, 622–624 [1946]) provides the following equation for the effect of a uniform resistance on velocity profile:

$$\frac{V_{2,\max}}{V} = \sqrt{\frac{(V_{1,\max}/V)^2 + \alpha_2 - \alpha_1 + \alpha_2 K}{1 + K}} \tag{6-154}$$

Here, V is the area average velocity, K is the number of velocity heads of pressure drop provided by the uniform resistance, $\Delta p = K\rho V^2/2$, and α is the velocity profile factor used in the mechanical energy bal-

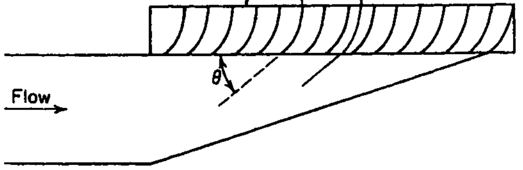


FIG. 6-36 Turning vanes in a slot distributor.

$$f \equiv \frac{D\Delta P}{2\rho V^2 L} \tag{6-32}$$

$$\mathrm{Re} \equiv \frac{DV\rho}{\mu} \tag{6-33}$$

For smooth pipe, the friction factor is a function only of the Reynolds number. In rough pipe, the relative roughness ϵ/D also affects the friction factor. Figure 6-9 plots f as a function of Re and ϵ/D. Values of ϵ for various materials are given in Table 6-1. The Fanning friction factor should not be confused with the Darcy friction factor used by Moody (*Trans. ASME*, **66**, 671 [1944]), which is four times greater. Using the momentum equation, the stress at the wall of the pipe may be expressed in terms of the friction factor:

$$\tau_w = f\,\frac{\rho V^2}{2} \tag{6-34}$$

Laminar and Turbulent Flow Below a **critical Reynolds number** of about 2,100, the flow is laminar; over the range 2,100 < Re < 5,000 there is a transition to turbulent flow. For laminar flow, the Hagen-Poiseuille equation

$$f = \frac{16}{\mathrm{Re}}, \qquad \mathrm{Re} \le 2{,}100 \tag{6-35}$$

may be derived from the Navier-Stokes equation and is in excellent agreement with experimental data. It may be rewritten in terms of volumetric flow rate, $Q = V\pi D^2/4$, as

$$Q = \frac{\pi \Delta P D^4}{128\mu L}, \qquad \mathrm{Re} \le 2{,}100 \tag{6-36}$$

TABLE 6-1 Values of Surface Roughness for Various Materials*

Material	Surface roughness ε, mm
Drawn tubing (brass, lead, glass, and the like)	0.00152
Commercial steel or wrought iron	0.0457
Asphalted cast iron	0.122
Galvanized iron	0.152
Cast iron	0.259
Wood stove	0.183–0.914
Concrete	0.305–3.05
Riveted steel	0.914–9.14

* From Moody, *Trans. Am. Soc. Mech. Eng.*, **66**, 671–684 (1944); *Mech. Eng* **69**, 1005–1006 (1947). Additional values of ε for various types or conditions concrete wrought-iron, welded steel, riveted steel, and corrugated-metal pip are given in Brater and King, *Handbook of Hydraulics*, 6th ed., McGraw-Hi New York, 1976, pp. 6-12–6-13. To convert millimeters to feet, multiply 3.281 × 10^{-3}.

For turbulent flow in smooth tubes, the Blasius equation gives t friction factor accurately for a wide range of Reynolds numbers.

$$f = \frac{0.079}{\mathrm{Re}^{0.25}}, \qquad 4{,}000 < \mathrm{Re} < 10^5 \tag{6-3}$$

The Colebrook formula (Colebrook, *J. Inst. Civ. Eng.* [*London*], 133–156 [1938–39]) gives a good approximation for the f-Re-(ϵ/ data for rough pipes over the entire turbulent flow range:

$$\frac{1}{\sqrt{f}} = -4 \log\left[\frac{\epsilon}{3.7D} + \frac{1.256}{\mathrm{Re}\sqrt{f}}\right] \qquad \mathrm{Re} > 4{,}000 \tag{6-}$$

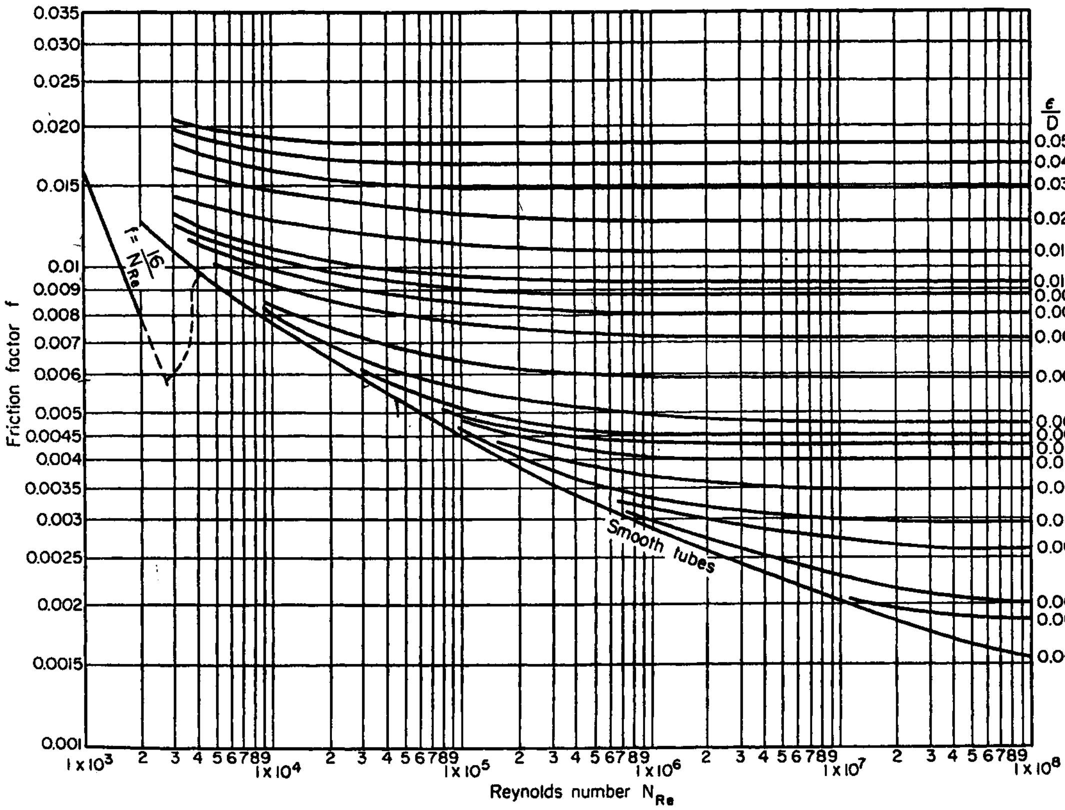


FIG. 6-9 Fanning Friction Factors. Reynolds number Re = $DV\rho/\mu$, where D = pipe diameter, V = velocity, ρ = fluid density, and μ = fluid viscosity. (*Based on Moody*, Trans. ASME, *66, 671* [*1944*].)

PERRY'S CHEMICAL ENGINEERS' HANDBOOK

SEVENTH EDITION

Robert H. Perry
Don W. Green

Environmental Resources Management

620 Bercut Drive · Sacramento, CA 95814
(916) 444-9378 · Fax (916) 444-5313

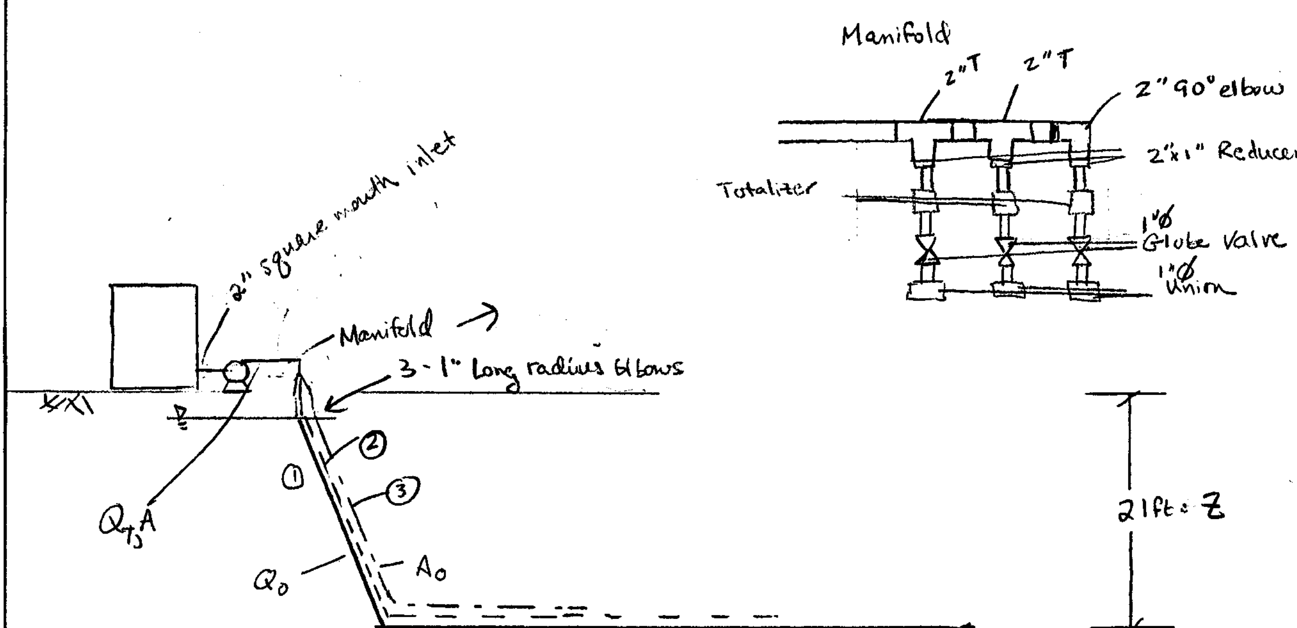
Project: Pang Site 11 95% Design	Project No. ______	Sheet 1	of 4
Subject: Pump	By: Heather Lee	Date: 9/17/01	
	Chkd. by ______	Date ______	

Purpose: Determine size of pump needed to injection $KMnO_4$

Method: Flow Loss

Assumptions:

- It take 12 in H_2O per foot of water above screen to overcome the pressure cause by water
- Screen depth is 21 ft
- Design water level is 3 ft bgs (water level varies seasonally from 3 to 8 ft bgs).
- Design flow rate: $Q_T = 30$ gpm with each piped having a $Q = 10$ gpm
- Smooth pipe.



Pipe 1
$d = 1$ in $= 0.0254$ m
$id = 1.05$ in $= 0.02667$
Screen length, $L_{S_1} = 150'$
blank length, $L_{B_1} = 300' + 300'$
$= 600'$
$= 183$ m

Pipe 2
$d = 1$ in
$id = 1.05$ in
Screen length $= 150' = 45.7$ m
blank length $= 300' + 150'$
$= 450'$
$= 137$ m

Pipe 3
$d = 1$ in
$id = 1.05$ in
Screen length, $L_{S_1} = 150$
blank length, $L_{B_1} = 300'$
$= 91$ m

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Project PANG Site 11 95% Design	Project No.	Sheet 2 of 4	
Subject Pump	By Nathan Lee	Date 9/17/01	
	Chkd. by	Date	

① Determine required pressure to overcome hydrostatic pressure

$$h_{wp} = 12 \frac{\text{in } H_2O}{ft} (21ft - 3ft)$$

$$h_{wp} = 216 \text{ in } H_2O$$

② Determine minor losses from pump to well casing using Equivalent lengths

1 - 2" - 90° standard elbow = 6.2 ft .... Harringtons pg 58
2 - 2" - Standard T = 2(12) ft --- Harrington pg 58
3 - 1" - Globe valves = (29.7)3 ft --- Harrington pg 58
3 - 1" - Totalizers = 29.7 ft – assume same as globe valve
3 - 1" - Long radius elbows = 3(1.7 ft) --- Haringtons pg 58
Assume 20 ft of 2 in hose prior to pump
Assume 30 ft for 2"×1" reducer
Assume 2 ft for unions

$$h_{m_{2"}} = 20 + 2(12) + 6.2$$
$$= 50.2 ft = 15.3 m$$

$$h_{m_{1"}} = 3(29.7) + 3(29.7) + 3(1.7) + 3(30) + 3(2)$$
$$= 279.3 ft = 85.1 m$$

2" ⌀ piping

$$\text{Velocity}, V_2 = \frac{Q_T}{A}$$

$$= \frac{30\frac{gal}{min} \times \frac{1 min}{60 s} \times \frac{1 ft^3}{7.48 gal}}{\frac{\pi}{4}\left(\frac{2.049}{12}\right)^2}$$

$$= 2.92 ft/s$$
$$= 0.89 m/s$$

$$Re_2 = \frac{\rho V D}{\mu}$$

$$= \frac{1000\frac{kg}{m^3}(0.89 m/s)(0.052 m)}{0.001 Pa \cdot s}$$

$$= 4.6 \times 10^4$$

from moody diagram w/ $Re_2 = 4.6 \times 10^4$ and smooth pipe

$f = 0.021$

$$h_{fm_2} = f \frac{L}{D} \frac{V^2}{2g}$$

$$= 0.021 \left(\frac{15.3 m}{0.052 m}\right) \frac{(0.89 m/s)^2}{2(9.866 m/s^2)}$$

$$= 0.25 m$$
$$= 9.8 in$$

1" ⌀ Piping

$$\text{Velocity}, V_1 = \frac{Q_o}{A_o}$$

$$V_1 = \frac{10\frac{gal}{min} \times \frac{1 min}{60 sec} \times \frac{1 ft^3}{7.48 gal}}{\pi/4 \left(1.05/12\right)^2}$$

$$V_1 = 3.71 ft/s$$
$$V_1 = 1.1 m/s$$

$$Re_1 = \frac{\rho V D}{\mu}$$

$$= \frac{1000\frac{kg}{m^3}(1.1 m/s)(0.02667)}{0.001}$$

$$= 2.9 \times 10^4$$

from moody diagram w/ $Re_1 = 2.9 \times 10^4$ and smooth pipe

$f = 0.023$

$$h_{fm_1} = f \frac{L}{D} \frac{V^2}{2g}$$

$$= 0.023 \left(\frac{85.1 m}{0.02667 m}\right) \frac{(1.1 m/s)^2}{2(9.866 m/s^2)}$$

$$= 4.5 m$$
$$= 177 in$$

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Project PANG Site 11 95% Design Project No. ______ Sheet 3 of 4
Subject Pump By Heather Lee Date 9/17/01
Chkd. by ______ Date ______

③ Determine friction losses in blank section of each pipe

Pipe 1

Velocity in each pipe, $V = \frac{Q_p}{A_o}$

$$= \frac{10\frac{gal}{min} \times \frac{1 min}{60 s} \times \frac{1 ft^3}{7.48 gal}}{\frac{\pi}{4}\left(\frac{1.05}{12}\right)^2}$$

$= 3.71$ ft/s

$= 1.1$ m/s

Reynold's number, $Re_o = \frac{\rho V D}{\mu}$

$$= \frac{1000\,kg/m^3\,(1.1\,m/s)(0.02667)}{0.001}$$

$\doteq 2.9 \times 10^4$

from moody diagram w/ $Re = 2.9 \times 10^4$ and smooth pipe
$f = 0.023$

$h_{f_{b1}} = f \frac{L}{D} \frac{V^2}{2g}$ where L is the entire blank pipe

$h_{f_{b1}} = 0.023 \left(\frac{183\,m}{0.02667\,m}\right)\left(\frac{(1.1)^2}{2(9.866)}\right)$

$\cong 9.7$ m of water column

$= 382$ in H_2O

Pipe 2

$h_{f_{b2}} = 0.023 \left(\frac{137\,m}{0.02667\,m}\right)\left(\frac{(1.1)^2}{2(9.866)}\right)$

$= 7.25$ m water column

$= 285$ in H_2O

Pipe 3

$h_{f_{b3}} = 0.023 \left(\frac{91}{0.02667}\right)\left(\frac{(1.1)^2}{2(9.866)}\right)$

$\cong 4.81$ m water column

$= 189$ in H_2O

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Project PANG 95% Design — Project No. ____ Sheet 4 of 4
Subject Pump — By Heather Lee — Date 9/17/01
Chkd. by ____ Date ____

④ Determine Pressure loss in the perforated section of pipe from Well screen design calculations

$$\Delta p = \left(\frac{4fL}{3D} - 2K\right)\rho\frac{V^2}{2}$$

where $K = 0.5$

f = fanning friction factor

$f_1 = 0.006$ for $Re = 2.8\times10^4$ at the beginning w/ smooth pipe

$f_2 = 0.012$ for $Re = 2545$ at the end of pipe

$\therefore f = \frac{0.006+0.012}{2}$

$f = 0.009$

$$\Delta p = \left[\frac{4(0.009)(45.7)}{3(0.026)} - 2(0.5)\right]\frac{1000\,\frac{kg}{m^3}(1.1)^2\,m^2/s^2}{2}$$

$\Delta p = 1.2\times10^4$ Pa

$\Delta p = 48.2$ in H_2O

⑤ Determine greatest pressure loss in pipe

Pipe 1

$h_{f_1} = 382\text{ in }H_2O + 48.2\text{ in }H_2O$

$= 430\text{ in }H_2O$ — * greatest pressure loss

Pipe 2

$h_{f_2} = 285\text{ in }H_2O + 48.2\text{ in }H_2O$

$= 333.2\text{ in }H_2O$

Pipe 3

$h_{f_3} = 189\text{ in }H_2O + 48.2$

$= 237.2\text{ in }H_2O$

⑥ Determine total pressure loss from pump

$h_T = h_{wp} + h_{fm_1} + h_{fm_2} + h_{f_1}$

$h_T = 216 + 9.8 + 177 + 430$

$h_T = 832.8\text{ in }H_2O$

Add 25% Factor of Safety

$h_T = 1041\text{ in }H_2O$

$h_T = 87\text{ ft }H_2O$

∴ pump must be able to pump 30 gal per minute at 87 ft of head.

Environmental Resources Management

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Project PANG 95% Design | Project No. ______ | Sheet 1 of 2
Subject SVE System – Vapor Concentrations | By Heather Lee | Date 6/6/01
Chkd. by ______ | Date ______

Purpose: To determine vapor concentration for the SVE System Design

Method: DiGuilio Equation
From Evaluation of Soil Venting Appication

Assumptions:
- Soil concentrations based on the arithmetic average of the soil concentration from the 1999 excavation confirmation samples and boring concentrations to the west of the impermeable barrier.
  Note: 1/2 Project screening goal was used for non detections.
  See attached spreadsheet entitled "Soil Concentration Data"
- Magnitude of liquid hydrocarbons present in soil is negligible
- Soils are sufficiently moist.
- Bulk Density = 1.855 g/cm^3
- Porosity = 0.3
- Volumetric water content = 0.25
- Volumetric air content = 0.2
- Fraction organic content = 0.003 see attached Table (Represent values of TOC)
- SVE system is located in fine and wet sand (Permeability ≈ 0.8)
- Blower efficiency of 10%
- SVE system operation for 2 years at 180 days per year.

Calculations:

DiGuilio Equation

$$① \text{---} \quad C_g = \frac{C_t}{\frac{a * K_d}{H} + C}$$

where
C_g = Vapor concentration of VOC (mg/cm^3)
C_t = Total volatile organic concentration (mg/cm^3)
a = Bulk Density (g/cm^3)
K_d = $K_{oc} \cdot f$
K_{oc} = Organic carbon-water partition coef (cm^3/g)
f = Fraction of organic content
H = Henry's Constant
C = Volumetric air content

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Project PANG Site 11 95% Design   Project No. ______   Sheet 2 of 2
Subject SVE System - Vapor Concentrations   By Heather Lee   Date 6/6/01
Chkd. by ______   Date ______

Example Calculation

Vinyl Chloride to west of barrier

Average Soil concentration = 5.2 ug/kg

Molecular weight = 63 g/mol

H = 1.1

$K_{oc} = 19 \frac{cm^3}{g}$

From Equation (1)

$$C_g = \frac{\left(5.2 \frac{ug}{kg_{soil}} * \frac{1.855\ g_{soil}}{cm^3} \times \frac{mg}{1000\ ug} \times \frac{1\ kg\ soil}{1000\ g\ soil}\right)}{\frac{1.855 \frac{g}{cm^3} \times \left(19 \frac{cm^3}{g} * 0.003\right)}{1.1} + 0.2}$$

$$C_g = 3.26 \times 10^{-5} \frac{mg}{cm^3}$$

Change to ug/L

$$C_g = 3.26 \times 10^{-5} \frac{mg}{cm^3} \times \frac{1000\ cm^3}{1\ L} \times \frac{1000\ ug}{1\ mg}$$

$$C_g = 32.6 \frac{ug}{L}$$

Change to ppmv

$$C_g = 32.6 \frac{ug}{L} \times \frac{24.04}{63\ g/gmol}$$ by Ideal gas law

$$C_g = 12.4 \text{ ppmv}$$

This Cg value is based on the predicted equilibrium concentration only. Previous experience has shown that a better estimate of the initial concentration is 1/10 of those values. Therefore Cg actual = 1.24 ppm.
See attached spreadsheet for values.

Soil Concentration Data
In Situ Treatment of Impacted Groundwater and Soil at IRP Site 11
Portland Air National Guard
Portland International Airport
Portland, Oregon

Soil concentrations from the soil samples collected to the west of the barrier.

	CS4-090199-6	CS7-090199-3.5	CS8-090199-3.5	GP11-12@2	GP11-12@5	Maximum	Average
TPH-gas	**1910**	20	20	20	20	1910	398
TPH-diesel	**532**	50	50	50	50	532	146.4
Soil concentrations are in milligram/kilogram (ppm)							
cis-1,2-DCE	10	**36.3**	10	10	10	36.3	15.3
PCE	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Benzene	**56.6**	1	**2.07**	1	1	56.6	12.3
Vinyl Chloride	0.35	**7.66**	**7.77**	**5**	**5**	7.77	5.2
Chlorobenzene	**776**	35	35	35	35	776	183
1,4-DCB	**498**	50	50	50	50	498	140
Soil concentrations are in microgram/kilogram (ppb)							

Soil concentrations were found in EE/CA report Figure 2-12
All dections above PSGs shown in bold.
All non-dect results assumed at one half the Project Screening Goals .

Soil Vapor Concentration Data
In Situ Treatment of Impacted Groundwater and Soil at IRP Site 11
Portland Air National Guard
Portland International Airport
Portland, Oregon

ASSSUMED SOIL PROPERTIES

Bulk Density(a)	1.855	g/cm3
Porosity	0.2	
Volumetric Water Content(b)	0.25	
Volumetric Air Content(c)	0.2	
Fraction Organic Content	0.003	

Chemical	Organic Carbon Water Coefficient (cm3/g) Koc	Soil/Water Distribution Coeff (Koc*Foc) (cm3/g) Kd	Henry's Law Constant (Dimensionless) H	Average Soil Concentration (µg/kg)	Total Volative Organic Concentration (mg/cm3) Ct	Estimated Vapor (mg/cm3) Cg	Estimated Vapor Concentration (µg/l)	Estimated Vapor Concentration (ppmv)	Actual Designed Vapor Concentration (ppmv)
Concentrations to the west of the barrier only									
TPH gasoline	2.00E+02	6.00E-01	3.00E-01	3.98E+05	7.38E-01	1.89E-01	188821	41,266	4,127
cis-1,2-DCE	3.60E+01	1.08E-01	1.70E-01	1.53E+01	2.84E-05	2.06E-05	21	5.10	0.51
PCE	2.70E+02	8.10E-01	7.50E-01	1.50E+00	2.78E-06	1.26E-06	1	0.18	0.02
Benzene	6.20E+02	1.86E+00	2.30E-01	1.23E+01	2.28E-05	1.50E-06	2	0.46	0.05
Vinyl Chloride	1.90E+01	5.70E-02	1.10E+00	5.20E+00	9.65E-06	3.26E-05	32.57	12.43	1.24
Chlorobenzene	2.20E+02	6.60E-01	1.50E-01	1.83E+02	3.39E-04	4.06E-05	41	8.87	0.89
1,4-DCB	6.20E+02	1.86E+00	1.00E-01	1.40E+02	2.60E-04	7.48E-06	7	1.20	0.12

Assuming
magnitude of liquid hydorcarbons present in soild is negligible
soil are sufficiently moist

Equations
Ct = average soil concentration * bulk density
Kd=Koc*Foc
Cg=Ct/((a*Kd/H) + c) From *Evaluation of Soil Venting Application* by Dominic C. DiGiulio

where,
a=Bulk density (kg/l)
b=Volumetric water content within soil volume (dimesionless)
c=Volumetric air content within soil volume (dimesionless)
Kd=Distribution coefficient(l/kg)
H=Henry's Law Constant (dimensionless)

(1) Henry's Law Constant and Koc for TPH gas based on Xylene

Draft - Revision 1

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TECHNICAL PROTOCOL FOR EVALUATING NATURAL ATTENUATION OF CHLORINATED SOLVENTS IN GROUNDWATER

by

Todd H. Wiedemeier, Matthew A. Swanson, David E. Moutoux, and E. Kinzie Gordon
Parsons Engineering Science, Inc.
Denver, Colorado

Dr. John T. Wilson, Dr. Barbara H. Wilson, and Dr. Donald H. Kampbell
United States Environmental Protection Agency*
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
Ada, Oklahoma

Jerry E. Hansen and Patrick Haas
Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base, Texas

Dr. Francis H. Chapelle
United States Geological Survey
South Carolina

November 1996

for

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas

*This United States Air Force guidance was developed in cooperation with United States Environmental Protection Agency (USEPA) researchers but was not issued by the USEPA and does not represent USEPA guidance.

Table C.3.3

Representative Values of Total Organic Carbon for Common Sediments

exture	Depositional Environment	Fraction Organic Carbon	Site Name
edium sand	fluvial-deltaic	0.00053 - 0.0012	Hill AFB, Utah
ne sand		0.0006 - 0.0015	Bolling AFB, D.C.
ne to coarse sand	back-barrier (marine)	0.00026 - 0.007	Patrick AFB, Florida
ganic silt and peat	glacial (lacustrine)	0.10 - 0.25	Elmendorf AFB, Alaska
ty sand	glaciofluvial	0.0007 - 0.008	Elmendorf AFB, Alaska
with sand, gravel d clay (glacial till)	glacial moraine	0.0017 - 0.0019	Elmendorf AFB, Alaska
dium sand to gravel	glaciofluvial	0.00125	Elmendorf AFB, Alaska
ess (silt)	eolian	0.00058 - 0.0016	Offutt AFB, Nebraska
ne - medium sand	glaciofluvial or glaciolacustrine	< 0.0006 - 0.0061	Truax Field, Madison Wisconsin
ne to medium sand	glaciofluvial	0.00021 - 0.019	King Salmon AFB, Fire Training Area, Alaska
			Dover AFB, Delaware
ne to coarse sand	glaciofluvial	0.00029 - 0.073	Battle Creek ANGB, Michigan
nd	fluvial	0.0057	Oconee River, Georgia[a/]
arse silt	fluvial	0.029	Oconee River, Georgia[a/]
edium silt	fluvial	0.020	Oconee River, Georgia[a/]
ne silt	fluvial	0.0226	Oconee River, Georgia[a/]
silt	lacustrine	0.0011	Wildwood, Ontario[b/]
ne sand	glaciofluvial	0.00023 - 0.0012	Various sites in Ontario[b/]
edium sand to gravel	glaciofluvial	0.00017 - 0.00065	Various sites in Ontario[b/]

Karickhoff, 1981

Domenico and Schwartz (1990)

The next step is to determine the distribution coefficient, K_d. Values of K_{oc} for chlorinated olvents and BTEX are obtained from Tables B.2.1 and B.2.2, respectively, and are listed in ble C.3.4.

For trichloroethene the most conservative (i.e., that value giving the highest solute velocity) is = 87 L/kg, and (using equation C.3.13):

$$K_d = \left(87\frac{L}{kg}\right)(0.007) = 0.61\frac{L}{kg}$$

The retarded contaminant velocity is given by (equation C.3.10):

United States Environmental Protection Agency | Office of Research and Development | Office of Solid Waste and Emergency Response | EPA/540/S-92/004 April 1992

EPA Ground Water Issue

Evaluation of Soil Venting Application

Dominic C. DiGiulio*

Introduction

The Regional Superfund Ground-Water Forum is a group of scientists, representing EPA's Regional Superfund Offices, organized to exchange up-to-date information related to ground-water remediation at Superfund sites. One of the major issues of concern to the Forum is the transport and fate of contaminants is soil and ground water as related to subsurface remediation.

The ability of soil venting to inexpensively remove large amounts of volatile organic compounds (VOCs) from contaminated soils is well established. However, the time required using venting to remediate soils to low contaminant levels often required by state and federal regulators has not been adequately investigated. Most field studies verify the ability of a venting system to circulate air in the subsurface and remove, at least initially, a large mass of VOCs. They do not generally provide insight into mass transport limitations which eventually limit performance, nor do field studies generally evaluate methods such as enhanced biodegradation which may optimize overall contaminant removal. Discussion is presented to aid in evaluating the feasibility of venting application. Methods to optimize venting application are also discussed.

For further information contact Dominic DiGiulio (405)332-8800 or FTS 700-743-2271 at RSKERL-Ada.

Determining Contaminant Volatility

The first step in evaluating the feasibility of venting application at a hazardous waste site is to assess contaminant volatility. If concentrations of VOCs in soil are relatively low and the magnitude of liquid hydrocarbons present in the soil is negligible, VOCs can be assumed to exist in a three-phase system (i.e., air, water, and soil), as illustrated in Figure 1. If soils are sufficiently moist, relative volatility in a three-phase system can be estimated using equation (1) which incorporates the effects of air-water partitioning (Henry's constant) and sorption (soil-water partition coefficient).

$$\frac{C_g}{C_t} = \frac{1}{(\rho_g K_{oc} f_{oc} / h) + \phi} \qquad (1)$$

where:

C_g = Vapor concentration of VOCs in gas phase(mg/cm³ air)
C_t = Total volatile organic concentration (mg/cm³ soil)
ρ_g = Bulk density (g/cm³)
K_{oc} = Organic carbon-water partition coefficient (cm³/g)
f_{oc} = Fraction of organic carbon content (g/g)
K_h = Henry's Constant (mg/cm³air/mg/cm³water)
θ = Volumetric moisture content (cm³/cm³)
ϕ = Volumetric air content (cm³/cm³)

Caution must be exercised when using this approach since this relationship is based on the assumption that solid phase sorption is dominated by natural organic carbon content. This assumption is frequently invalid in soils below the root zone where soil organic carbon is less than 0.1%.

* *Environmental Engineer, Robert S. Kerr Environmental Research Laboratory*

Communication • Training • Technology Support Project • Technology Support

Superfund Technology Support Center for Ground Water

Robert S. Kerr Environmental Research Laboratory
Ada, Oklahoma

Technology Innovation Office
Office of Solid Waste and Emergency Reponse, U.S. EPA, Washington, DC

Walter W. Kovalick, Jr., Ph.D., Director

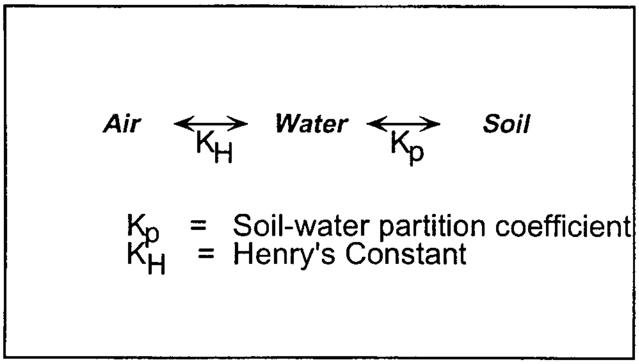

Figure 1. Three phase system.

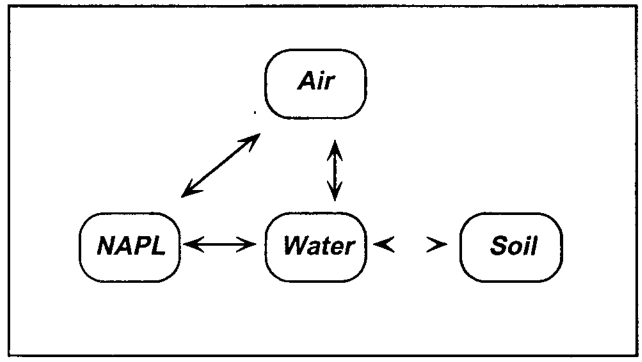

Figure 2. Four phase system.

Equation (1) can be used to evaluate individual VOC contaminant reduction trends and attainment of soil-based remediation standards. Vapors should be collected from dedicated vapor probes under static (venting system not operating) conditions. This estimate is valid only for soils in the immediate vicinity of the probe intake. This approach minimizes sample dilution and collection of vapor samples under nonequilibrium conditions. It, however, necessitates periodic cessation of venting. When the vapor concentration for a VOC approaches a corresponding total soil concentration, actual soil samples can be collected to confirm remediation. This approach has several benefits over conventional soil samples collection and analysis. At lower VOC concentration levels, collection of static vapor samples is likely more sensitive than soil collection and analysis due to VOC loss in the latter procedure. Siegrist and Jenssen (1990) demonstrated substantial VOC loss during normal soil sample collection, storage, and analysis. Also, comparing contaminant reduction trends strictly with soil samples is difficult due to spatial variability in soils. No two soil samples can be collected at the exact same location. In addition, soil gas analyses can be accomplished more quickly and inexpensively than soil sample collection, thus enabling more frequent evaluation of trends. A potential disadvantage of using this approach is inability to distinguish VOC vapors emanating from soils as opposed to ground water. Hypothetically, soils could be remediated to desired levels with probes still indicating contamination above remediation standards. This concern could be alleviated to some degree by determining the presence of a diffusion vapor gradient from the water table using vertically placed vapor probes.

If soils are visibly contaminated or the presence of nonaqueous phase liquids (NAPLs) is suspected in soils based on high contaminant, total organic carbon, or total petroleum hydrocarbon analysis, contaminants are likely present in a four phase system as illustrated in Figure 2. Under these circumstances, most of the VOC mass will be associated with the immiscible fluid and assuming that the fluid acts as an ideal solution, volatilization will be governed by Raoult's Law.

$$P_a = X_a P^o_a \qquad (2)$$

where:

P_a = vapor pressure of component over solution (mm Hg)
X_a = mole fraction of component in solution
P^o_a = saturated vapor pressure of pure component (mm Hg)

In a four-phase system, contaminant volatility will be governed by the VOC's vapor pressure and mole fraction within the immiscible fluid. The vapor pressure of all compounds increases substantially with an increase in temperature while solubility in a solvent phase is much less affected by temperature. This suggests that soil temperature should be taken into account when evaluating VOC recovery for contaminants located near the soil surface (seasonal variations in soil temperature quickly dampen with depth). For instance, if conducting a field test to evaluate potential remediation of shallow soil contamination in the winter, one should realize that VOC recovery could be substantially higher during summer months, and low recovery should not necessarily be viewed as venting system failure.

As venting proceeds, lower molecular weight organic compounds will preferentially volatilize and degrade. This process is commonly described as weathering and has been examined by Johnson (1989) in laboratory experiments. Samples of gasoline were sparged with air and the concentration and composition of vapors were monitored. The efficiency of vapor extraction decreased to less than 1% of its initial value even though approximately 40% of the gasoline remained. Theoretical and experimental work on product weathering indicate the need to monitor temporal variation in specific VOCs of concern in extraction and observation wells.

Evaluating Air Flow

Air permeability (k_a) in soil is a function of a soil's intrinsic permeability (k_i) and liquid content. At hazardous waste sites, liquid present in soil pores is often a combination of soil water and immiscible fluids. Air permeability (k_a) can be estimated by multiplying a soil's intrinsic permeability (k_i) by the relative permeability (k_r).

$$k_a = k_i k_r \qquad (3)$$

The dimensionless ratio k_r varies from one to zero and describes the variation in air permeability as a function of air saturation. Equations developed by Brooks and Corey (1964) and Van Genuchten (1980) are useful in estimating air permeability as a function of air saturation or liquid content. The Brooks-Corey equation to estimate relative permeability of a non-wetting fluid (i.e. air) is given by:

$$k_r = (1 - S_e)^2 \ (1 - S_e^{(2+\lambda)/\lambda}) \qquad (4)$$

where:

S_e = effective saturation
λ = a pore distribution parameter

The effective saturation is given by:

$$S_e = \frac{\left(\frac{\theta}{\varepsilon} + \frac{\theta_r}{\varepsilon}\right)}{\left(1 - \frac{\theta_r}{\varepsilon}\right)} \qquad (5)$$

Where:

θ = volumetric moisture content
ε = total porosity
θ_r = residual saturation

The pore size distribution parameter and residual water content can be estimated using soil-water characteristic curves which relate matric potential to volumetric water content. When initially developing an estimate of relative permeability for a given soil texture and liquid content, values for ε, θ_r, S_e, and λ can be obtained from the literature. Rawls et al. (1982) summarized geometric and arithmetic means for Brook-Corey parameters for various USDA soil textural classes. Figure 3 illustrates relative permeability as a function of volumetric moisture content for clayey soils assuming ε = 0.475, θ_r = 0.090, and λ = 0.131.

The most effective method of measuring air permeability is by conducting a field pneumatic pump test. Using permeameters or other laboratory measurements provide information on a

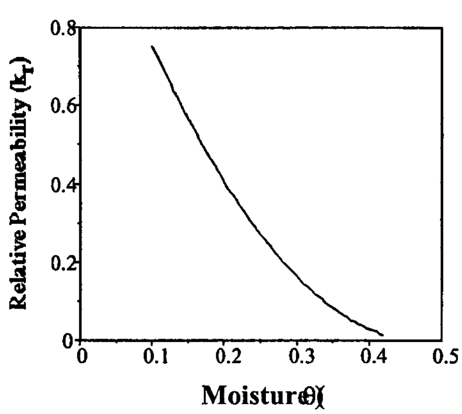

Figure 3. Relative permeability vs moisture content of clay.

relatively small scale. Information gained from pneumatic pump tests is vital in determining site-specific design considerations (e.g., spacing of extraction wells). Selecting the placement and screened intervals of extraction and observation wells and applied vacuum rates during a pump test is often based on preliminary mathematical modeling.

Evaluating Mass Transfer Limitations and Remediation Time

The effects of mass transport limitations are usually manifested by a substantial drop in soil vapor contaminant

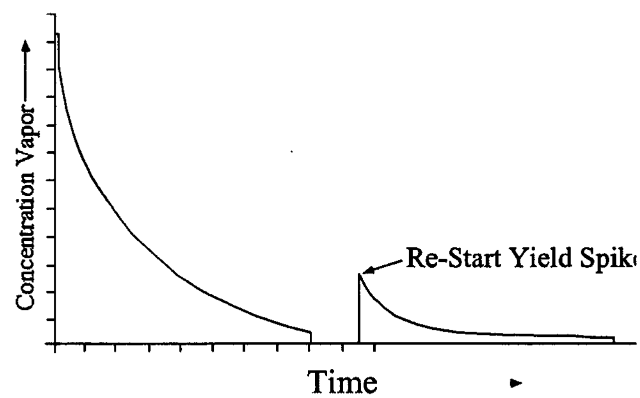

Figure 4. Concentration vs. time.

concentrations as illustrated in Figure 4 or by an asymptotic increase in total mass removal with operation time. Typically, when venting is terminated, an increase in soil gas concentration is observed over time. Slow mass transfer with respect to advective air flow is most likely caused by diffusive release from porous aggregate structures or lenses of lesser permeability as illustrated in Figure 5. The time required for the remediation of heterogeneous and fractured soils depends on the proportion of contaminated material exposed to direct bulk airflow. It would be expected that long-term performance of venting will be limited to a large degree by gaseous and liquid diffusion from soil regions not exposed to direct airflow.

Regardless of possible causes, the significance of mass transport limitations should be evaluated during venting field tests. This can be achieved by pneumatically isolating a small area of a site and aggressively applying vacuum extraction until mass transport limitations are realized. Isolation can be achieved by surrounding extraction wells with passive inlet or air injection wells as shown in Figure 6. Quantifying the effects of mass transport limitations on remediation time might then be attempted by utilizing models incorporating mass transfer rate coefficients.

The discrepancy frequently observed between mass removal predicted from equilibrium conditions using Henry's Law constants and that observed from laboratory column and field studies is sometimes reconciled by the use of "effective or lumped" soil-air partition coefficients. These parameters are

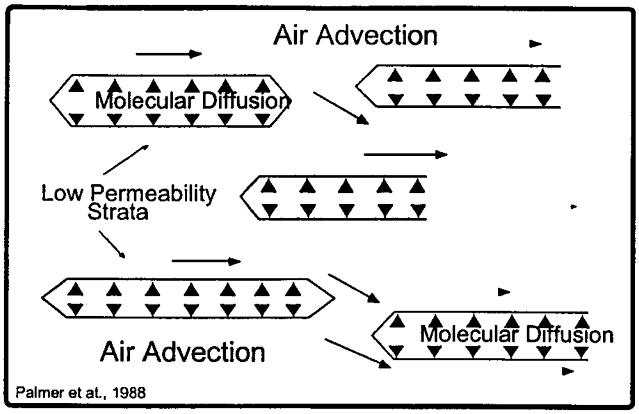

Figure 5. Effect of Low Permeability Lenses.

determined from laboratory column tests and are then used for model input to determine required remediation times. While this method does indirectly account for mass transport limitations, problems may arise when one attempts to quantitatively describe several processes with lumped parameters. The primary concern is whether the lumped parameter is suitable for use only under the laboratory conditions from which it was determined, or whether it can be transferred for modeling use in the field. Perhaps the most direct method of accounting for mass transport limitations would be to incorporate diffusive transfer directly into convective-dispersive vapor transport models.

Enhanced Aerobic Biodegradation

With the exception of a few field research projects, soil vacuum extraction has been applied primarily for removal of volatile organic compounds from the vadose zone. However, circulation of air in soils can be expected to enhance the aerobic biodegradation of both volatile and semivolatile organic compounds. One of the most promising uses of this technology is in manipulating subsurface oxygen levels to maximize in-situ biodegradation. Bioventing can reduce vapor treatment costs and can result in the remediation of semivolatile organic compounds which cannot be removed by physical stripping alone.

Venting circulates air in soils at depths much greater than are possible by tilling, and oxygen transport via the gas phase is much more effective than injecting or flooding soils with oxygen saturated liquid solutions.

Hinchee (1989) described the use of soil vacuum extraction at Hill AFB, Utah for oxygenation of the subsurface and the enhancement of biodegradation of petroleum hydrocarbons in soils contaminated with JP-4 jet fuel. Figures 7 and 8 illustrate subsurface oxygen profiles at the Hill site prior to and during venting. It is evident that soil oxygen levels dramatically increased following one week of venting. Soil vapor samples collected from observation wells during periodic vent system shutdown revealed rapid decreases in oxygen concentration and corresponding CO_2 production suggesting that aerobic biodegradation was occurring at the site. Laboratory treatability studies using soils from the site demonstrated increased carbon-dioxide evolution with increasing moisture content when enriched with nutrients. It is worthwhile to note that soils at Hill AFB were relatively dry at commencement of field vacuum extraction indicating, that the addition of moisture could perhaps stimulate aerobic biodegradation even further under field operating conditions.

When conducting site characterization and field studies, it is recommended that CO_2 and O_2 levels be monitored in soil vapor probes and extraction well offgas to allow the assessment of basal soil respiration and the effects of site management on subsurface biological activity. These measurements are simple and inexpensive to conduct and can yield a wealth of information regarding:

1. The mass of VOCs and semivolatiles which have undergone biodegradation versus volatilization. This information is crucial if subsurface conditions (e.g., moisture content) are to be manipulated to enhance biodegradation to reduce VOC offgas treatment costs and maximize semivolatile removal.

2. Factors limiting biodegradation. If O_2 and CO_2 monitoring

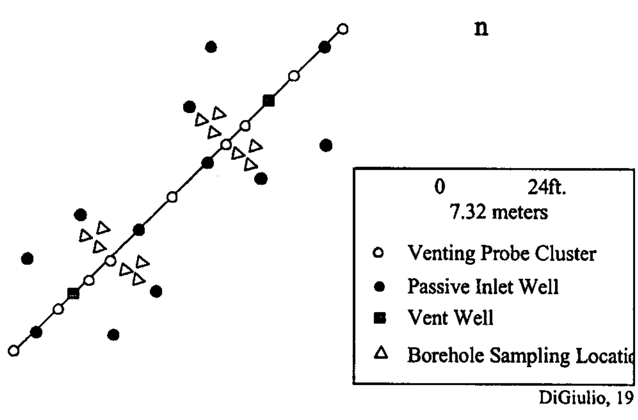

Figure 6. Proposed Pilot Test Design.

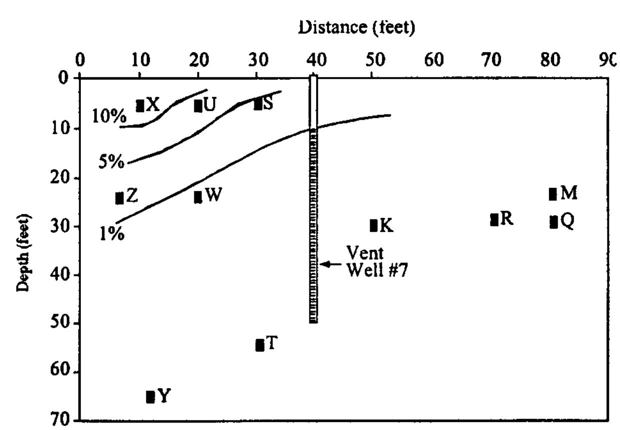

Figure 7. Oxygen concentration in vadose zone before venting.

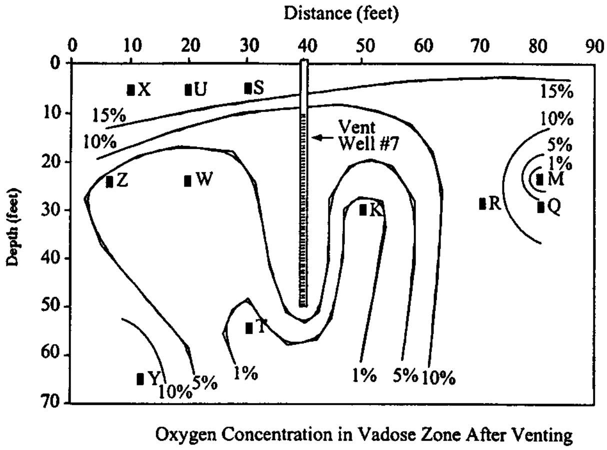

Figure 8. Oxygen concentration in vadose zone after venting.

reveals low O_2 consumption and CO_2 generation while readily biodegradable compounds persist in soils, further characterization studies could be conducted to determine if biodegradation is being limited by insufficient moisture content, toxicity (e.g. metals), or nutrients.

3. Subsurface air flow characteristics. Observation wells which indicate persistent, low O_2 levels may indicate an insufficient supply of oxygenated air at that location suggesting the need for air injection, higher extraction well vacuum, additional extraction wells, or additional soils characterization which may indicate high moisture content or the presence of immiscible fluids impeding the flow of air.

Location and Number of Vapor Extraction Wells

One of the primary objectives in conducting a venting field test is to evaluate the initial placement of extraction wells to optimize VOC removal from soil. Placement of extraction wells and selected applied vacuum is largely an iterative process requiring continual re-evaluation as additional data are collected during remediation. Vacuum extraction wells produce complex three-dimensional reduced pressure zones in affected soils. The size and configuration of this affected volume depends on the applied vacuum, venting geometry (e.g., depth to water table), soil heterogeneity, and intrinsic (e.g., permeability) and dynamic (e.g., moisture content) properties of the soil. The lateral extent of this reduced pressure zone (beyond which static vacuum is no longer detected) is often termed the radius or zone of influence (ROI). Highly permeable sandy soils typically exhibit large zones of influence and high air flow rates whereas less permeable soils, such as silts and clays, exhibit smaller zones of influence and low air flows.

Measured or anticipated radii of influence are often used to space extraction wells. For instance, if a ROI is measured at 10 feet, extraction wells are placed 20 feet apart. However, this strategy is questionable since vacuum propagation and air velocity decrease substantially with distance from an extraction well. Thus, only a limited volume of soil near an extraction well will be effectively ventilated regardless of the ROI. Johnson (J.J., 1988) describes how the addition of 13 extraction wells within the ROI of other extraction wells increased blower VOC concentration by 4000 ppmv and mass removal by 40 kg/day. They concluded that the radius of influence was not an effective parameter for locating extraction wells and that operation costs could be reduced by increasing the number of extraction wells as opposed to pumping at higher rates with fewer wells.

Determining the propagation of induced vacuum requires conducting pneumatic pump tests in which variation in static vacuum is measured in vapor observation wells at depth and distance from extraction wells. Locating extraction and observation wells along transects as illustrated in Figure 4 minimizes the number of observation wells necessary to evaluate vacuum propagation at linear distances from extraction wells. Pressure differential can be observed at greater distances than would otherwise be possible in other configurations.

Propagation of vacuum in soils as a function of applied vacuum can be determined by conducting pneumatic pump tests with incrementally increasing flow or applied vacuum. Vacuum is increased after steady state conditions (relatively constant static vacuum measurements in observation wells) exist in soils from the previously applied vacuum. A step pump test will indicate a significant increase in static vacuum or air velocity with increasing applied vacuum near an extraction well. However, at distance from an extraction well, a significant increase in static vacuum will not be observed with an increase in applied vacuum. Pneumatic pump tests allow determination of radial distances from extraction wells in which air velocity is sufficient to ensure remediation.

After the initial placement of extraction wells has been established based on the physics of air flow, an initial applied vacuum must be selected to ensure optimal VOC removal. In regard to mass transfer considerations, the vent rate should be increased if a significant corresponding mass flux is observed. Even though an increased venting rate may not substantially increase the propagation of vacuum with distance, air velocity will increase near the extraction well. If most contaminants are in more permeable deposits, an increase in applied vacuum will increase mass removal eventually to a point of diminishing returns or until the system is limited by diffusion. Note that this strategy is for optimization of volatilization not biodegradation. Optimizing in-situ biodegradation often necessitates reducing air velocity in soil. As a result, vapor treatment costs are minimized but overall mass flux decreases. Thus, in-situ biodegradation of VOCs minimizes overall costs but may extend venting operation time.

During a field test, it is desirable to operate until mass transport limitations are realized in order to evaluate the long term performance of the technology. This can be achieved by isolating small selected areas of a site by the use of passive air inlet wells. When attempting to evaluate diffusion limited mass removal in isolated areas, applied vacuum should remain high and the distance between passive inlet and extraction wells should be minimized. Too often, venting field tests are conducted for relatively short periods of time (e.g., 2 - 21 days) which only results in assessment of air permeability and initial mass removal. Longer field studies (e.g., 6 months - 12 months) enable better insight into mass transfer limitations which eventually govern venting effectiveness.

Screened Interval

The screened interval of extraction wells will play a significant role in directing air flow through contaminated soils. Minimum depths are recommended by some practitioners for venting operation to avoid short-circuiting of air flow. However, the application of venting need not be limited by depth to water table since horizontal vents can be used in lieu of vertically screened extraction wells to remediate soils with shallow contamination. Often, it is desirable to dewater contaminated shallow aquifer sediments for venting application. For remediation of more permeable soils with deep contamination, an extraction well should be screened at the maximum depth of contamination or to the seasonal low water table, whichever is shallowest, to direct air flow and reduce short-circuiting. For less permeable soils, or for more continuous vertical contamination, a higher and longer screened interval may be useful. In stratified systems, such as in the presence of clay layers between more permeable deposits, more than one well will be required, each venting a distinct strata. Screening an extraction well over two strata of significantly different permeability will result in most air flow being directed only in the strata of greater permeability. It is important to screen extraction wells over the interval of highest soil contamination to avoid extracting higher volumes of air at lower vapor concentration.

During venting, the reduced pressure in the soil will cause an upwelling of the water table. The change in water table elevation can be determined from the predicted radial pressure distribution. Johnson et al. (1988) indicated that upwelling can be significant under typical venting conditions. Water table rise will cause contaminated soil lying above the water table to become saturated, resulting in decreased mass removal rates. Ground water upwelling due to venting system operation can be minimized with concurrent water table dewatering.

Placement of Observation Wells

Observation wells are essential in determining whether contaminated soils are being effectively ventilated and in the evaluation of interactions among extraction wells. The more homogeneous and isotropic the unsaturated medium, the fewer the number of vapor monitoring probes required. To adequately describe vacuum propagation during a field test, usually at least three observation well clusters are needed within the ROI of an extraction well. At least one of these clusters should be placed near an extraction well because of the logarithmic decrease in vacuum with distance. The depth and number of vapor probes within a cluster depends on the screened intervals of extraction wells and soil stratigraphy. However, vertical placement of vapor probes might logically be near the soil-water table interface, soil horizon interfaces, and near the soil surface. As previous mentioned, the use of air flow modeling can assist in optimizing the depth and placement of vapor observation wells and in the interpretation of data collected from these monitoring points.

When constructing observation wells it is desirable to minimize vapor storage volume in the screened interval and sample transfer line. This will minimize purging volumes and ensure a representative vapor sample in the vicinity of each observation well. Analysis of soil gas in an on-site field laboratory is preferred to provide real time data for implementation of engineering controls and process modifications. It is recommended that steel canisters, sorbent tubes, or direct GC injection be used in lieu of Tedlar bags when possible because of potential VOC loss through bag leakage or diffusion within the teflon material itself. This problem may lead to erroneous analytical results and the potential of a false negative indication of soil remediation at low soil gas concentrations.

Summary/Conclusions

While the application of soil vacuum extraction is conceptually simple, its success depends on understanding complex subsurface physical, chemical, and biological processes which provide insight into factors limiting venting performance. Optimizing venting performance is critical when attempting to meet stipulated soil-based clean-up levels required by regulators. The first step in evaluating a venting application is to assess contaminant volatility. Volatility is a function of a contaminant's soil-water partition coefficient and Henry's constant if present in a three-phase system, and a contaminant's vapor pressure and mole fraction in an immiscible fluid, if present in a four phase system. Volatility is greatly decreased when soils are extremely dry. As vacuum extraction proceeds, lower molecular weight organic compounds preferentially volatilize and biodegrade. Decreasing mole fractions of lighter compounds and increasing mole fractions of heavier compounds affect observed offgas concentrations. Understanding contaminant volatility is necessary when attempting to utilize offgas vapor concentrations as an indication of venting progress.

The significance of mass transport limitations should be evaluated during venting field tests. Long term performance of venting will most likely be limited by diffusion from soil regions of lesser permeability which are not exposed to direct airflow. Mass transport limitations can be assessed by isolating a small area of a site and aggressively applying vacuum extraction. Simplistic methods to evaluate remediation time should be avoided. One of the most promising uses of vacuum extraction is in manipulating subsurface oxygen levels to enhance biodegradation. When conducting field studies, it is recommended that CO_2 and O_2 levels be monitored in vapor probes to evaluate the feasibility of VOC and semivolatile contaminant biodegradation.

Air permeability in soil is a function of a soil's intrinsic permeability and liquid content. Relative permeability of air can be estimated using relationships developed by Brooks and Corey (1964) and Van Genuchten (1980). The most effective method of measuring air permeability is by conducting pneumatic pump tests. Information gained from pneumatic pump tests can be used to determine site-specific design considerations such as the spacing of extraction wells. Measured or anticipated zones of influence are not particularly useful in spacing extraction wells. Extraction wells should be located to maximize air velocity in contaminated soils.

Pneumatic pump tests with increasing applied vacuum may be useful in determining radial distances from extraction wells in which air velocity is sufficient to ensure remediation. Screened intervals should be located at or below the depth of contamination. In stratified soils, more than one well is necessary to ventilate each strata. At least three observation well clusters are usually necessary to observe vacuum propagation within the radius of influence of an extraction well. Logical vertical placement of vapor probes might be near the soil-water table interface, soil horizon interfaces, and near the soil surface.

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Environmental Resources Management

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(916) 444-9378 · Fax (916) 444-5313

Project Pang Site 11 95% Design	Project No. 6101.52	Sheet 1 of 1	
Subject SVE System - Blower Pressure Calcs	By Heather Lee	Date 6/6/01	
	Chkd. by	Date	

Purpose: Determine vaccum requirements for the blower.

Method: Use soil permeability to determine vacuum

Assumptions:

SVE horizontal wells located in fine and wet sand with a permeability of 0.8

50 scfm blower

Length of screen: 100 ft

- Length of pipe was measured from contract drawings
- Each pipe approximately 104 ft long
- Each pipe has alternating 20 ft sections of screen and blank pipe
- Total screen is 100 ft

Calculations:

Using attached Isotherm

Permeability of 0.8

- with applied vacuum Pw of 6 in Hg, approximate Flow rate is 0.71 $\frac{\text{scfm}}{\text{ft screen}}$

- with 100 foot screen, vapor flow rate = 71 scfm

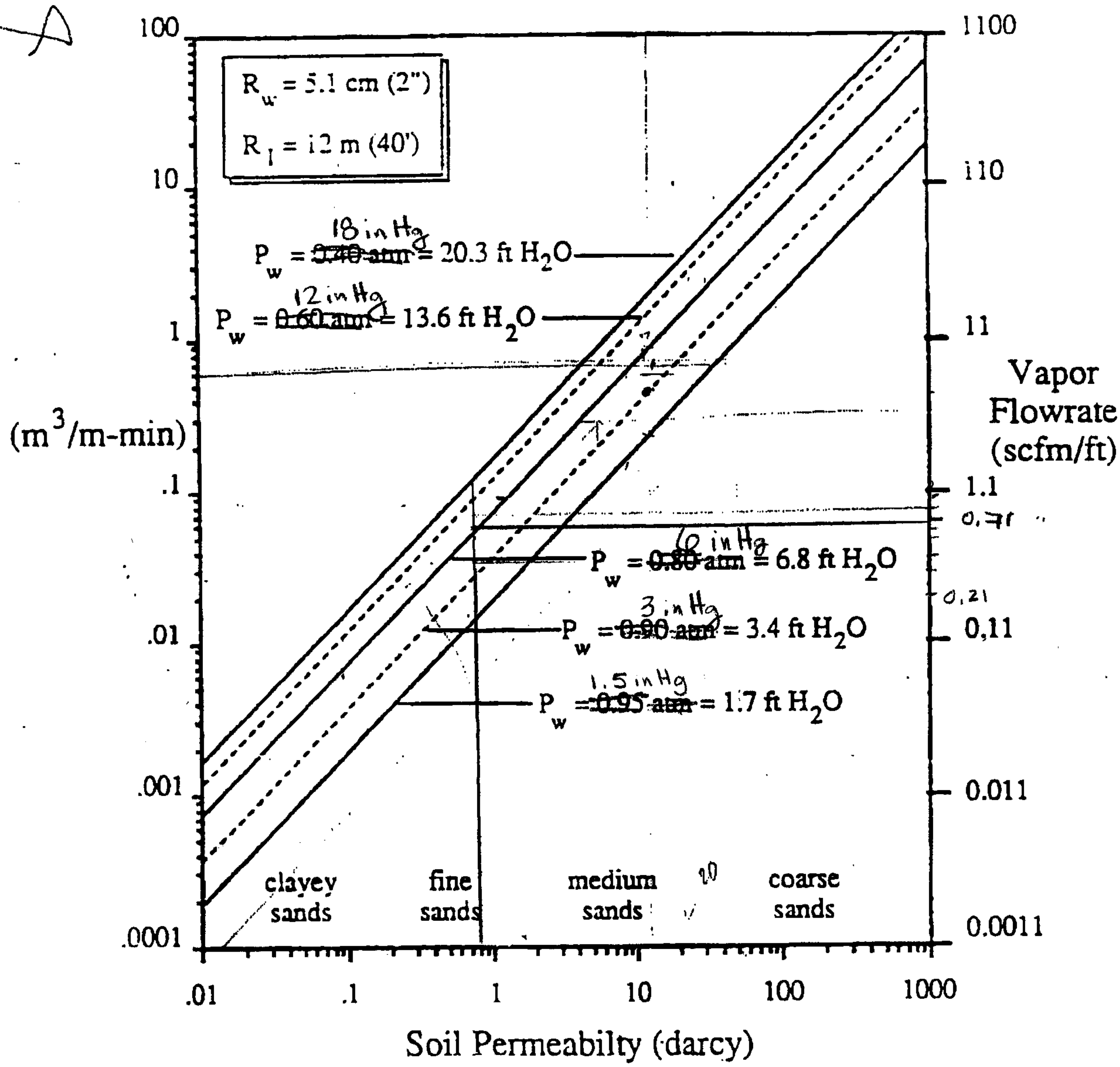
- 71 scfm > 50 scfm

∴ 6 in Hg vacuum is sufficient.

Check the pressure losses in the pipe

From Crane Tables (attached) for air flowing through 4" pipe at 60°F and 14.7 psia, no pressure drop occurs until flowing at 375 cfm, We are way below that so the pressure losses in the pipe do not need to be accounted for.

∴ Blower size 50 scfm at 6 in Hg vacuum



[ft H_2O] denote vacuums expressed as equivalent water column heights

Figure E-5. Predicted Steady-State Flowrates (per unit well screen depth) for a Range of Soil Permeabilities and Applied Vacuums (P_w).

Flow of Air Through Schedule 40 Steel Pipe

For lengths of pipe other than 100 feet, the pressure drop is proportional to the length. Thus, for 50 feet of pipe, the pressure drop is approximately one-half the value given in the table . . . for 300 feet, three times the given value, etc.

The pressure drop is also inversely proportional to the absolute pressure and directly proportional to the absolute temperature.

Therefore, to determine the pressure drop for inlet or average pressures other than 100 psi and at temperatures other than 60 F, multiply the values given in the table by the ratio:

$$\left(\frac{100+14.7}{P+14.7}\right)\left(\frac{460+t}{520}\right)$$

where:

"P" is the inlet or average gauge pressure in pounds per square inch, and,

"t" is the temperature in degrees Fahrenheit under consideration.

The cubic feet per minute of compressed air at any pressure is inversely proportional to the absolute pressure and directly proportional to the absolute temperature.

To determine the cubic feet per minute of compressed air at any temperature and pressure other than standard conditions, multiply the value of cubic feet per minute of free air by the ratio:

$$\left(\frac{14.7}{14.7+P}\right)\left(\frac{460+t}{520}\right)$$

Calculations for Pipe Other than Schedule 40

To determine the velocity of water, or the pressure drop of water or air, through pipe other than Schedule 40, use the following formulas:

$$v_a = v_{40}\left(\frac{d_{40}}{d_a}\right)^2$$

$$\Delta P_a = \Delta P_{40}\left(\frac{d_{40}}{d_a}\right)^5$$

Subscript "a" refers to the Schedule of pipe through which velocity or pressure drop is desired.

Subscript "40" refers to the velocity or pressure drop through Schedule 40 pipe, as given in the tables on these facing pages.

Free Air q'_m Cubic Feet Per Minute at 60 F and 14.7 psia	Compressed Air Cubic Feet Per Minute at 60 F and 100 psig	Pressure Drop of Air In Pounds per Square Inch Per 100 Feet of Schedule 40 Pipe For Air at 100 Pounds per Square Inch Gauge Pressure and 60 F Temperature								
		1/8″	1/4″	3/8″	1/2″					
1	0.128	0.361	0.083	0.018						
2	0.256	1.31	0.285	0.064	0.020					
3	0.384	3.06	0.605	0.133	0.042	3/4″				
4	0.513	4.83	1.04	0.226	0.071					
5	0.641	7.45	1.58	0.343	0.106	0.027				
6	0.769	10.6	2.23	0.408	0.148	0.037	1″			
8	1.025	18.6	3.89	0.848	0.255	0.062	0.019			
10	1.282	28.7	5.96	1.26	0.356	0.094	0.029	1¼″	1½″	
15	1.922	...	13.0	2.73	0.834	0.201	0.062			
20	2.563	...	22.8	4.76	1.43	0.345	0.102	0.026		
25	3.204	...	35.6	7.34	2.21	0.526	0.156	0.039	0.019	
30	3.845	...	...	10.5	3.15	0.748	0.219	0.055	0.026	
35	4.486	...	...	14.2	4.24	1.00	0.293	0.073	0.035	
40	5.126	...	...	18.4	5.49	1.30	0.379	0.095	0.044	
45	5.767	...	...	23.1	6.90	1.62	0.474	0.116	0.055	2″
50	6.408			28.5	8.49	1.99	0.578	0.149	0.067	0.019
60	7.690	2½″		40.7	12.2	2.85	0.819	0.200	0.094	0.027
70	8.971			...	16.5	3.83	1.10	0.270	0.126	0.036
80	10.25	0.019		...	21.4	4.96	1.43	0.350	0.162	0.046
90	11.53	0.023		...	27.0	6.25	1.80	0.437	0.203	0.058
100	12.82	0.029	3″		33.2	7.69	2.21	0.534	0.247	0.070
125	16.02	0.044			...	11.9	3.39	0.825	0.380	0.107
150	19.22	0.062	0.021		...	17.0	4.87	1.17	0.537	0.151
175	22.43	0.083	0.028		...	23.1	6.60	1.58	0.727	0.205
200	25.63	0.107	0.036	3½″	...	30.0	8.54	2.05	0.937	0.264
225	28.84	0.134	0.045	0.022		37.9	10.8	2.59	1.19	0.331
250	32.04	0.164	0.055	0.027		...	13.3	3.18	1.45	0.404
275	35.24	0.191	0.066	0.032		...	16.0	3.83	1.75	0.484
300	38.45	0.232	0.078	0.037		...	19.0	4.56	2.07	0.573
325	41.65	0.270	0.090	0.043		...	22.3	5.32	2.42	0.673
350	44.87	0.313	0.104	0.050	4″	...	25.8	6.17	2.80	0.776
375	48.06	0.356	0.119	0.057	0.030	...	29.6	7.05	3.20	0.887
400	51.26	0.402	0.134	0.064	0.034	...	33.6	8.02	3.64	1.00
425	54.47	0.452	0.151	0.072	0.038	...	37.9	9.01	4.09	1.13
450	57.67	0.507	0.168	0.081	0.042	...	...	10.2	4.59	1.26
475	60.88	0.562	0.187	0.089	0.047		...	11.3	5.09	1.40
500	64.08	0.623	0.206	0.099	0.052		...	12.5	5.61	1.55
550	70.49	0.749	0.248	0.118	0.062		...	15.1	6.79	1.87
600	76.90	0.887	0.293	0.139	0.073		...	18.0	8.04	2.21
650	83.30	1.04	0.342	0.163	0.086	5″	...	21.1	9.43	2.60
700	89.71	1.19	0.395	0.188	0.099	0.032		24.3	10.9	3.00
750	96.12	1.36	0.451	0.214	0.113	0.036		27.9	12.6	3.44
800	102.5	1.55	0.513	0.244	0.127	0.041		31.8	14.2	3.90
850	108.9	1.74	0.576	0.274	0.144	0.046		35.9	16.0	4.40
900	115.3	1.95	0.642	0.305	0.160	0.051	6″	40.2	18.0	4.91
950	121.8	2.18	0.715	0.340	0.178	0.057	0.023	...	20.0	5.47
1 000	128.2	2.40	0.788	0.375	0.197	0.063	0.025	...	22.1	6.06
1 100	141.0	2.89	0.948	0.451	0.236	0.075	0.030	...	26.7	7.29
1 200	153.8	3.44	1.13	0.533	0.279	0.089	0.035	...	31.8	8.63
1 300	166.6	4.01	1.32	0.626	0.327	0.103	0.041	...	37.3	10.1
1 400	179.4	4.65	1.52	0.718	0.377	0.119	0.047			11.8
1 500	192.2	5.31	1.74	0.824	0.431	0.136	0.054			13.5
1 600	205.1	6.04	1.97	0.932	0.490	0.154	0.061	8″		15.3
1 800	230.7	7.65	2.50	1.18	0.616	0.193	0.075			19.3
2 000	256.3	9.44	3.06	1.45	0.757	0.237	0.094	0.023	10″	23.9
2 500	320.4	14.7	4.76	2.25	1.17	0.366	0.143	0.035		37.3
3 000	384.5	21.1	6.82	3.20	1.67	0.524	0.204	0.051	0.016	
3 500	448.6	28.8	9.23	4.33	2.26	0.709	0.276	0.068	0.022	
4 000	512.6	37.6	12.1	5.66	2.94	0.919	0.358	0.088	0.028	
4 500	576.7	47.6	15.3	7.16	3.69	1.16	0.450	0.111	0.035	12″
5 000	640.8	...	18.8	8.85	4.56	1.42	0.552	0.136	0.043	0.018
6 000	769.0	...	27.1	12.7	6.57	2.03	0.794	0.195	0.061	0.025
7 000	897.1	...	36.9	17.2	8.94	2.76	1.07	0.262	0.082	0.034
8 000	1025	...	...	22.5	11.7	3.59	1.39	0.339	0.107	0.044
9 000	1153	...	...	28.5	14.9	4.54	1.76	0.427	0.134	0.055
10 000	1282	...	...	35.2	18.4	5.60	2.16	0.526	0.164	0.067
11 000	1410	...	...	...	22.2	6.78	2.62	0.633	0.197	0.081
12 000	1538	...	...	...	26.4	8.07	3.09	0.753	0.234	0.096
13 000	1666	...	...	...	31.0	9.47	3.63	0.884	0.273	0.112
14 000	1794	...	...	...	36.0	11.0	4.21	1.02	0.316	0.129
15 000	1922	...	...	...	...	12.6	4.84	1.17	0.364	0.148
16 000	2051	...	...	...	...	14.3	5.50	1.33	0.411	0.167
18 000	2307	...	...	...	...	18.2	6.96	1.68	0.520	0.213
20 000	2563	...	...	...	...	22.4	8.60	2.01	0.642	0.260
22 000	2820	...	...	...	...	27.1	10.4	2.50	0.771	0.314
24 000	3076	...	...	...	...	32.3	12.4	2.97	0.918	0.371
26 000	3332	...	...	...	...	37.9	14.5	3.49	1.12	0.435
28 000	3588	...	...	...	...	...	16.9	4.04	1.25	0.505
30 000	3845	...	...	...	...	...	19.3	4.64	1.42	0.520

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Project PANG Site 11 95% Design — Project No. 610152 — Sheet 1 of 1
Subject Mass Calculation — By Heather Lee — Date 6/5/01
Chkd. by ______ Date ______

Purpose: Determine the mass of chemicals in the soil and the necessary carbon

Method: Mass balances

Assumptions:

- All soil areas based on the chemical contour (approximate extent of total petroleum hydrocarbons and volatile organic compounds above PRGs in soil) in Figure 2-12 of EE/CA
- All soil volumes assumed as a rec' box laying on its side
- 110 lb soil / cubic foot soil
- The soil concentrations are based on the average of the soil concentration from the 1999 excavation confirmation samples and boring concentrations either to the east or the west of the barrier. (see attached for values)
- A smear zone of 10 feet

Calculations

West of barrier (location of SVE piping)

① - Volume of Soil

$V_w = 17 ft \times 22 ft \times 10 ft + 9 ft \times 11 ft \times 10 ft$

$V_w = 4{,}730 ft^3$

② - Mass of Soil

$M_w = V_w \times \frac{wt\ soil}{Vol}$

$M_w = 4730 ft^3 \times \frac{110 lb}{ft^3}$

$M_w = 5.2 \times 10^5$ lb soil

③ - Mass of Chemical in soil

$M_{chem} = M_{soil} \times$ Concentration in soil

$M_{VC} = 5.2 \times 10^5 lb_{soil} \times \frac{5.2\ \mu g_{VC}}{kg_{soil}} \times \frac{1 kg_{soil}}{1000 g_{soil}} \times \frac{454 g_{soil}}{1 lb_{soil}} \times \frac{1 g_{VC}}{1 \times 10^6 \mu g_{VC}} \times \frac{1 lb}{454 g_{VC}}$

$M_{VC} = 0.0027$ lb vinyl chloride

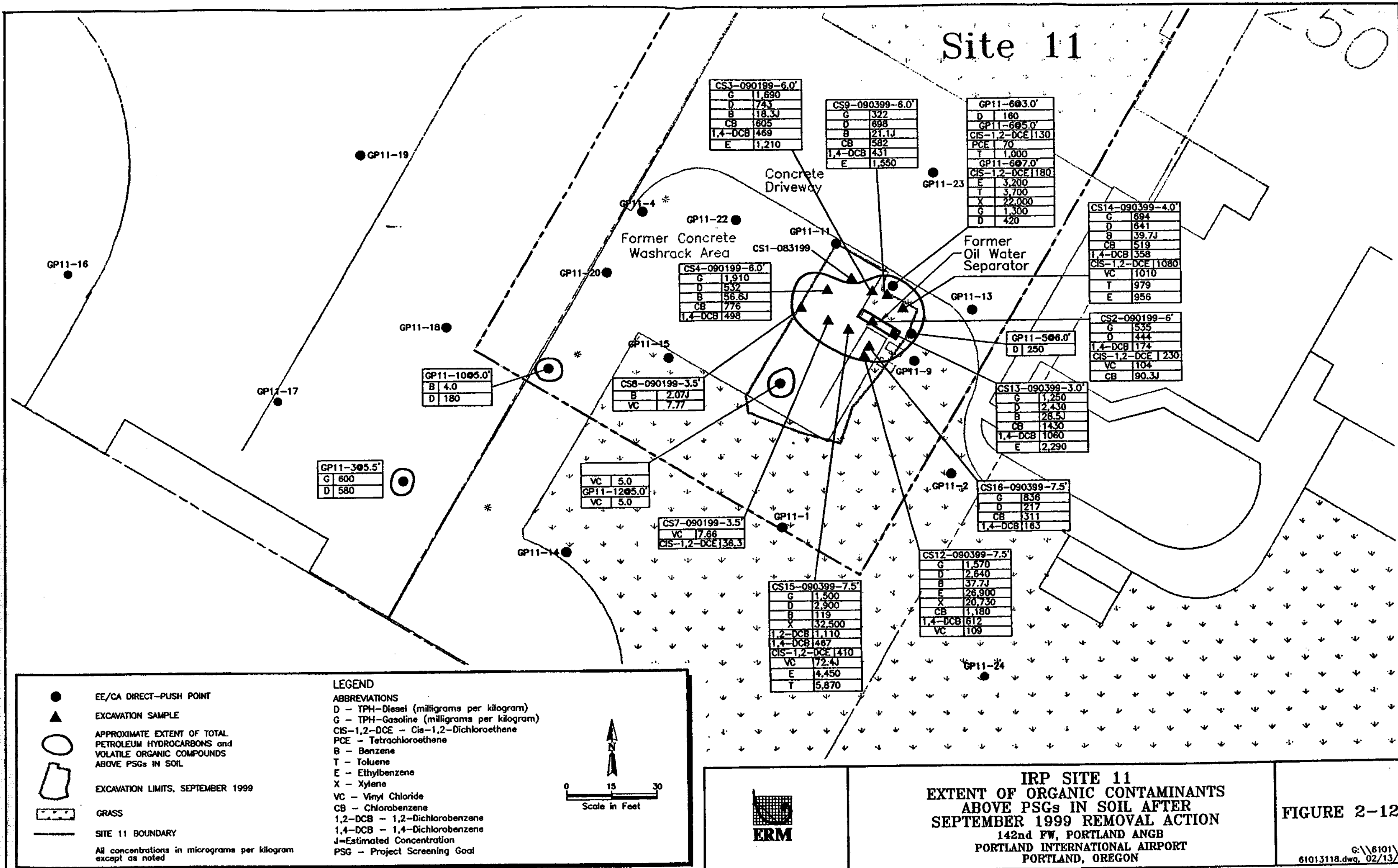
As shown on the attached spreadsheet, the total amount of chemicals in the soil is approximately 210 lbs. Because of the low mass in soil and the fact that the source has been removed, 2,200 lb carbon vessels have been chosen.

Soil Mass Data
In Situ Treatment of Impacted Groundwater and Soil at IRP Site 11
Portland Air National Guard
Portland International Airport
Portland, Oregon

	Average Soil Concentration (ppb)	Mass in Soil (lb)
Initial average soil concentrations from the soil samples collected to the west of the barrier.		
TPH-gas	398000	206.96
TPH-diesel	146400	76.13
cis-1,2-DCE	15.26	0.008
PCE	1.5	0.001
Benzene	12.334	0.006
Vinyl Chloride	5.156	0.003
Chlorobenzene	183.2	0.10
1,4-DCB	139.6	0.073

Mass in Soil = V * Wt * Cs

V = Volume of contaminated soil to the west of barrier, 520,000 ft^3
Wt = Weight of soil per volume, 110 lb/ft^3
Cs = Concentration of chemical in soil in ppb


Site 11
<50
CS3-090199-6.0'
G 1,690
D 743
B 18.3J
CB 605
1,4-DCB 469
E 1,210
CS9-090399-6.0'
G 322
D 698
B 21.1J
CB 582
1,4-DCB 431
E 1,550
GP11-6@3.0'
D 160
GP11-6@5.0'
CIS-1,2-DCE 130
PCE 70
T 1,000
GP11-6@7.0'
CIS-1,2-DCE 180
E 3,200
T 3,700
X 22,000
G 1,300
D 420
CS14-090399-4.0'
G 694
D 641
B 39.7J
CB 519
1,4-DCB 358
CIS-1,2-DCE 1080
VC 1010
T 979
E 956
CS2-090199-6'
G 535
D 444
1,4-DCB 174
CIS-1,2-DCE 230
VC 104
CB 90.3J
GP11-5@6.0'
D 250
CS13-090399-3.0'
G 1,250
D 2,430
B 28.5J
CB 1430
1,4-DCB 1060
E 2,290
CS16-090399-7.5'
G 836
D 217
CB 311
1,4-DCB 163
CS12-090399-7.5'
G 1,570
D 2,640
B 37.7J
E 26,900
X 20,730
CB 1,180
1,4-DCB 612
VC 109
CS15-090399-7.5'
G 1,500
D 2,900
B 119
X 32,500
1,2-DCB 1,110
1,4-DCB 467
CIS-1,2-DCE 410
VC 72.4J
E 4,450
T 5,870
CS4-090199-6.0'
G 1,910
D 532
B 56.6J
CB 776
1,4-DCB 498
CS8-090199-3.5'
B 2.07J
VC 7.77
CS7-090199-3.5'
VC 17.66
CIS-1,2-DCE 36.3
VC 5.0
GP11-12@5.0'
VC 5.0
GP11-10@5.0'
B 4.0
D 180
GP11-3@5.5'
G 600
D 580
Concrete Driveway
Former Concrete Washrack Area
Former Oil Water Separator
CS1-083199
GP11-1
GP11-2
GP11-4
GP11-9
GP11-11
GP11-13
GP11-14
GP11-15
GP11-16
GP11-17
GP11-18
GP11-19
GP11-20
GP11-22
GP11-23
GP11-24
LEGEND
EE/CA DIRECT-PUSH POINT
EXCAVATION SAMPLE
APPROXIMATE EXTENT OF TOTAL PETROLEUM HYDROCARBONS and VOLATILE ORGANIC COMPOUNDS ABOVE PSGs IN SOIL
EXCAVATION LIMITS, SEPTEMBER 1999
GRASS
SITE 11 BOUNDARY
All concentrations in micrograms per kilogram except as noted
ABBREVIATIONS
D – TPH-Diesel (milligrams per kilogram)
G – TPH-Gasoline (milligrams per kilogram)
CIS-1,2-DCE – Cis-1,2-Dichloroethene
PCE – Tetrachloroethene
B – Benzene
T – Toluene
E – Ethylbenzene
X – Xylene
VC – Vinyl Chloride
CB – Chlorobenzene
1,2-DCB – 1,2-Dichlorobenzene
1,4-DCB – 1,4-Dichlorobenzene
J=Estimated Concentration
PSG – Project Screening Goal
N
0 15 30
Scale in Feet
ERM
IRP SITE 11
EXTENT OF ORGANIC CONTAMINANTS ABOVE PSGs IN SOIL AFTER SEPTEMBER 1999 REMOVAL ACTION
142nd FW, PORTLAND ANGB
PORTLAND INTERNATIONAL AIRPORT
PORTLAND, OREGON
FIGURE 2-12
G:\\6101\31
61013118.dwg, 02/13/01

Environmental Resources Management

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(916) 444-9378 • Fax (916) 444-5313

Project PANG Site 11 95% Design   Project No. 610152   Sheet 1 of 2
Subject Bioventing Calcs   By Heather Lee   Date 6/1/01
"Bioventing Calcs#1" spreadsheet.   Chkd. by ______   Date ______

Purpose: Determine required flow rate for biodegradation of TPH diesel.

Method: Bioventing Calculations

Assumptions:

- Chemical Formula for TPHdiesel = $C_{13.8}H_{29.6}$
  ∴ Molecular weight = 195.2 g/mol
- Concentration of TPHdiesel = 600 mg/kg to West of barrier
- Volume of soil is a rec box. laying on its side with
  length = 30ft
  Height = 10ft
  Width = 23 ft
- 110 lb/cf soil
- molecular weight of air 28.8 g/mol air
- Volume air = 0.074 lb/cf
- operation of SVE system 180 days per year
- operating efficiency 1%

Calculations

① Mass balance for TPHdiesel

$$C_{13.8}H_{29.6} + 21.2(O_2 + 3.78\,N_2) \rightarrow 13.8\,CO_2 + 14.8\,H_2O + 80.1\,N_2$$

∴ 21.2 moles of air per mole TPHdiesel

② Volume Soil

Vol soil = 17 ft × 22 ft × 10 ft + 9 ft × 11 ft × 10 ft
= 4,730 ft³

③ Mass of Soil

Mass soil = Vol * $\frac{\text{weight soil}}{\text{Vol}}$
= 4730 ft³ × $\frac{110\text{ lb}}{\text{ft}^3}$
= 5.2×10⁵ lb soil

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Project PANG Site 11 95% Design Project No. 6101.52 Sheet 2 of 2
Subject BioVenting Calcs By Heather Lee Date 6/1/01
Chkd. by ______ Date ______

(4) Mass of TPH in soil

$Mass_{TPH} = Mass_{soil} * \text{Concentration in soil}$

$Mass_{TPH} = 5.2 \times 10^5 \text{ lb} * 146400 \text{ ppb} * 1 \times 10^{-9}$

$Mass_{TPH} = 76.1 \text{ lb TPH}$

(5) mols of TPH

$mol_{TPH} = mass_{TPH} / \text{molecular weight TPH}$

$= 76.1 \cancel{\text{lb}}_{TPH} * \frac{\text{mol TPH}}{195.2 \cancel{g}} * \frac{454 \cancel{g}}{\cancel{lb}}$

$= 177 \text{ mol TPH}$

(6) mol air needed to biovent

$mol_{air} = 21.2 * mol_{TPH}$

$= 21.2 * 177$

$= 3752 \text{ mol air}$

(7) Convert to volume of air

$Vol_{air} = \frac{mol_{air} * MW_{air}}{weight/vol_{air}}$

$= \frac{3752 \cancel{mol} * 28.8 \frac{g}{\cancel{mol}}}{0.074 \frac{\cancel{lb}}{ft^3} * \frac{454 g}{\cancel{lb}}}$

$= 3216$ cf of air req to be extracted to remediate TPH in soil

(8) Required SVE system flow rate

$Flow = \left(Vol_{air} / time * efficiency\right)$

$= \frac{3216}{\left(2 \cancel{yrs} \times \frac{180 \cancel{d}}{\cancel{yr}} \times \frac{24 \cancel{h}}{\cancel{d}} \times \frac{60 min}{1 \cancel{h}}\right) * 0.01}$

$= 0.0061$ cfm

Since blower operates at 50 scfm we are providing enough air to biovent the diesel.

APPENDIX D

MATERIAL SAFETY DATA SHEETS

MATERIAL SAFETY DATA SHEET
Potassium Permanganate

Date of Issue: October 1998

STATEMENT OF HAZARDOUS NATURE

Hazardous according to criteria of Worksafe Australia

COMPANY DETAILS

Company:	**ProSciTech**
Address:	PO Box 111, Thuringowa Central Qld. 4817 Australia
Street Address:	37 Framara Drive, Kelso, Qld, 4815. Australia
Telephone Number:	(07) 4774 0370
Fax Number:	(07) 4789 2313

IDENTIFICATION SECTION

Product Name	Potassium Permanganate
Other Names	Permanganic Acid. Potassium Salt.
Product Code	C364
U.N. Number	UN1490
Dangerous Goods Class and Subsidiary Risk	5.1
Hazchem Code	2Y
Poison Schedule	None allocated
Use	Fixative and stain in microscopy

Physical Description and Properties

Appearance	Dark purple to bronze crystals with no odour.
Boiling Point/Melting Point	M.P. 150^{o}C
Vapour Pressure	No data
Specific Gravity	2.70
Flash Point	No data
Flammability Limits	No data
Solubility in water	Moderate 1-10%

Other Properties

Ingredients

Chemical Name	**CAS Number**	**Proportion**
$KmnO_4$	07722-64-7	100%

HEALTH HAZARD INFORMATION

Health Effects:	
Acute	Target organs : respiratory system, central nervous system, blood, kidneys.
Swallowed:	May cause nausea, vomiting, gastrointestinal irritation and burns to the mouth and throat.
Eye:	May cause severe irritation and burns.
Skin:	May cause severe irritation and or burns. Substance readily absorbed through skin.Damaged skin is generally aggravated by exposure.
Inhaled:	Excessive inhalation of dust is irritating and may be severely damaging to respiratory passages and/or lungs.
Chronic:	Prolonged inhalation of manganese in the form of its inorganic compounds may cause manganism.

First Aid:

Swallowed:	Do not induce vomiting; if conscious give large amounts of water. Follow with diluted vinegar, fruit juice or whites of eggs, beaten with water. Call a physician.
Eye:	Wash continuously with water for 15 minutes. Call a physician.
Skin:	Wash continuously with water for 15 minutes
Inhaled:	Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult give oxygen. Call a physician.
First Aid Facilities:	Eye bath, safety shower

PRECAUTIONS FOR USE

Exposure Standards:	$5 mg/m^3$
Engineering Controls:	Use general or local exhaust ventilation to meet TLV requirements.
Personal Protection:	Respiratory Protection : None required where adequate ventilation conditions exist. If airborne concentration exceeds TLV, a dust/mist respirator is recommended. If concentration exceeds capacity of respirator, a self-contained breathing apparatus is advised. Eye/skin protection : Safety glasses with sideshields, uniform, butyl rubber gloves are recommended.
Flammability:	Use in well ventilated area

SAFE HANDLING INFORMATION

Storage and Transport:	Keep container tightly closed. Store separately and away from flammable and combustible materials. Keep from contact with clothing.
Spills and Disposal:	Wear self-contained breathing apparatus and full protective clothing. Keep combustibles (wood, paper, oil, etc.) away from spilled material. With clean shovel, carefully place material into clean, dry container and cover; remove from area. Flush spill area with water. Dispose in accordance with all applicable federal, state and local environmental regulations. EPA Hazardous Waste Number : D001 (ignitable waste).
Fire/Explosion Hazard:	In case of fire soak with water. Firefighters should wear proper protective equipment and self-contained breathing apparatus with full face piece operated in positive pressure mode. Move containers from fire area if it can be done without risk. Use water to keep fire-exposed containers cool.

OTHER INFORMATION

Incompatibilities (Materials to avoid)	Organic materials, combustible materials, strong reducing agents, strong acids, peroxides, alcohols, chemically active metals.
Animal Toxicity Data:	LD50 (Oral-Rat) - 1090mg/Kg. LD50 (SCU-Mouse) - 500mg/Kg.

The information published in this Material Safety Data Sheet has been compiled from data in various technical publications. It is the user's responsibility to determine the suitability of this information for adoption of necessary safety precautions. We reserve the right to revise Material Safety Data Sheets as new information becomes available. Copies may be made for non-profit use.

May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements.

PRODUCT NAME: PUREGOLD® CLEANDRILL

Section I MANUFACTURER'S INFORMATION

MANUFACTURER'S NAME & ADDRESS:

CETCO – *Drilling Products Group*
1350 West Shure Drive
Arlington Heights, IL 60004

Telephone Number: 847-392-5800 E-mail: www.cetco.com
EMERGENCY CONTACT: CHEMTREC 800-424-9300
Date Prepared: February 23, 1999

Section II HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

Hazardous Components (Specific Chemical Identity: Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (optional)

Proprietary Mixture: Synthetic and naturally occurring gums.

THIS PRODUCT DOES NOT CONTAIN ANY HAZARDOUS INGREDIENTS, REPORTABLE FOR SARA, TITLE III, SECTION 313.

PRODUCT IDENTIFICATION
Chemical Name: Mixture
Chemical Family: Not Applicable
NFPA/HMIS: Health - 0, Fire - 0, Reactivity - 0, Specific Hazard - See Section VI
DOT Class: Not Regulated

Section III PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point	- Not Applicable	Specific Gravity (H_2O = 1)	- Not Determined
Vapor Pressure (mm Hg.)	- Not Applicable	Melting Point	- Not Applicable
Vapor Density (AIR = 1)	- Not Applicable	Density	- 35 - 45 lbs./ft.^{3}
Solubility in Water	- Dispersible	pH	- 7.0 - 7.5 (2% slurry in water)
Appearance and Odor	- Tan powder, odorless.		

Section IV FIRE AND EXPLOSION HAZARD DATA

Flash Point (Method Used)	- Not Available		
Flammable Limits	- Not Available	LEL- -	UEL- -
Extinguishing Media	- Water, CO_2, Dry Powder or Foam.		
Special Fire Fighting Procedures	- Wear positive pressure, self-contained breathing apparatus and full protective equipment.		
Unusual Fire/Explosion Hazards	- Dust-air mixtures may be explosive, the minimum ignition temperature reported for gums, through 200 mesh, is 716°F (380°C). The minimum explosive concentration of a dust cloud is 0.04 oz./cu. ft. Avoid open lights, flames, welding and spark producing sources.		

Section V REACTIVITY DATA

Stability	- Stable under normal conditions of use, storage, handling and transportation.
Hazardous Polymerization	- Will Not Occur.
Conditions To Avoid	- Moderate to high humidity conditions, product will absorb moisture.
Incompatibility (Materials to Avoid)	- Strong Oxidizing agents.
Hazardous Decomposition or By-Products	- Oxides of Carbon

Section VI HEALTH HAZARD DATA

Health Hazards (Acute and Chronic):

Eyes:	May cause mild irritation.
Skin:	Prolonged exposure may cause slight skin irritation. A single prolonged exposure is not likely to result in material being absorbed through the skin in harmful amounts.
Inhalation:	Dust may cause irritation to upper respiratory tract.
Ingestion:	Not for human consumption.

Carcinogenicity: NTP? No IARC Monographs? No OSHA Regulated? No

Medical Conditions Generally Aggravated by Exposure: None Known.

Emergency and First Aid Procedures:

Eyes:	Flush with plenty of water for 15 minutes. Consult a physician if irritation persists.
Skin:	Wash thoroughly with soap and warm water. Consult physician if irritation occurs.
Inhalation:	If breathing is difficult, remove to fresh air; consult physician.
Ingestion:	Dilute by drinking large quantities of water and seek medical attention.

Section VII PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to be Taken in Case Material is Released or Spilled:
If product is spilled, vacuum or sweep up, as for any inert solid material such as sand or soil . Avoid dusting.

Waste Disposal Method:
Dispose according to Federal, State and Local Disposal and Discharge Laws.

Precautions to Be Taken in Handling and Storing:
Be sure to minimize generation of airborne dust.

PRODUCT NAME: PUREGOLD® CLEANDRILL

Section VIII CONTROL MEASURES

Respiratory Protection (Specify Type) - Use a NIOSH/MSHA (TC-21C-132) approved respirator as needed.

Ventilation	- Local Exhaust	- As Appropriate	Special	- None
	- Mechanical (General)	- As Appropriate	Other	- None

Eye Protection - Chemical safety goggles with face shield. Eye Wash stations should be available.
Skin Protection - Chemical gloves.
Other Protective Clothing or Equipment - None Known
Work/Hygienic Practices - Use good housekeeping practices.

May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements.

PRODUCT NAME: DRY ENZYME BREAKER (DEB)™

Section I MANUFACTURER'S INFORMATION

MANUFACTUERER'S NAME & ADDRESS:

CETCO - *Drilling Products Group*
1500 West Shure Drive
Arlington Heights, Illinois 60004

Telephone Number: 847-392-5800 / e-mail: www.cetco.com
EMERGENCY CONTACT: CHEMTREC 800-424-9300
Date Prepared: February 15, 2001

Section II HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

HAZARDOUS COMPONENTS: (Specific Chemical Identity: Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (optional)

CONTAINS NO HAZARDOUS INGREDIENTS.

PRODUCT IDENTIFICATION

Chemical Family: Powder Enzyme Protein
Formula: Proprietary.
NFPA/HMIS: Health - 0, Fire - 0, Reactivity - 0, Specific Hazard - See Section VI
DOT Class: Not Regulated (49 CFR, IMDG, IMO, ICAO / IATA).

Section III PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point: NA
Vapor Pressure (mm Hg.)**:** Unknown.
Vapor Density (AIR = 1)**:** Unknown.
Solubility in Water: Complete.
Appearance and Odor: White powder with mild odor.

Density (H_20=1)**:** NA
Melting Point: Less than 32^0 F
Evaporation Rate: Unknown.

Section IV FIRE AND EXPLOSION HAZARD DATA

This product is not combustible. Use extinguishing media suitable for surrounding materials. High concentrations of dust may present a potential dust explosion hazard.

PRODUCT NAME: DRY ENZYME BREAKER (DEB)™

Section V REACTIVITY DATA

Stability: Unstable -
Stable - X

Conditions to Avoid - High temperatures.

Incompatibility (Materials to Avoid): Strong acids, bases, oxidizing agents.

Hazardous Decomposition or By-products: None.

Hazardous Polymerization: May Occur -
Will Not Occur - X

Conditions to Avoid - None Known.

Section VI HEALTH HAZARD DATA

Route(s) of Entry: Inhalation? No Skin? Yes Ingestion? Yes

Health Hazards (Acute and Chronic)**:** See sections below.

Carcinogenicity: NTP? No IARC Monographs? No OSHA Regulated? No

CHRONIC OVEREXPOSURE: None known to occur. Individuals with a history of respiratory allergic responses may have respiratory conditions such as asthma intensified by exposure to dust from this product if allowed to dry.

Emergency and First Aid Procedures:

Skin: Essentially non-toxic. May produce a drying effect which can cause irritation on prolonged or repeated exposure. Wash skin with soap and water. Use a suitable skin lotion.

Eyes: May cause irritation upon direct contact depending on individual sensitivity. Remove material from eyes by flushing with fresh water. Consult physician if irritation persists.

Ingestion: Ingestion of this material may produce toxic effects. If ingested, consult a physician.

PRODUCT NAME: DRY ENZYME BREAKER (DEB)™

Section VII PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to be Taken in Case Material is Released or Spilled: Stop flow of material, surround spill to prevent spread. Do not allow material to dry on floor or other surfaces as dust may be irritating. Avoid producing air borne dust. Provide respiratory and skin protection.

Waste Disposal Method: Use pumps and containers as necessary to recover material. Salvage uncontained material, flush balance to drain. Completely flush spill area to avoid drying and dustiness.

Other Precautions: Do not get in eyes. Avoid contact with skin and clothing. Wash thoroughly after handling.

Section VIII CONTROL MEASURES

Respiratory Protection (Specify Type): Not required.

Ventilation	a) Local Exhaust	N/A	Special - Not Applicable
	b) Mechanical (General)	N/A	Other - None Known

Protective Gloves: Rubber, plastic, leather.
Eye Protection: Safety glasses
Other Protective Clothing or Equipment: None known.
Work/Hygienic Practices: Avoid contact and control spills. Remove material that may come in personal contact. Keep work area clear of spilled material and avoid contact. Personnel should be tested for protein enzyme sensitivity prior to work assignment in handling material.

APPENDIX E

BID FORM

BID FORM
Portland Air National Guard Base
Portland, Oregon

BID ITEM	DESCRIPTION	ESTIMATED QUANTITY	ESTIMATED UNIT	UNIT PRICE	BID QUANTITY	BID UNIT	BID AMOUNT
	Mobilization/Meetings						
1	Mobilization/demobilization	1	LS		1	LS	
	Well Installation						
2	Monitoring Well Installation (Section 02000)	1	LS		1	LS	
3	Injection Well Installation (Section 02100)	1	LS		1	LS	
3a	Soil Disposal (Class I Landfill)	50	CY			CY	
3b	Soil Disposal (Class II Landfill)	50	CY			CY	
3c	Water Disposal (Hazardous)	500	Gal			Gal	
3d	Water Disposal (non-Hazardous)	500	Gal			Gal	
4	Potassium Permanganate Solution Injection (Section 02200)	1	LS		1	LS	
5	Quarterly Groundwater Monitoring (Section 02300)	1	LS		1	LS	
	Soil Vapor Extraction System						
6	Soil Vapor Extraction System (including installation and electrical work) (Section 02400)	1	LS		1	LS	
7	Operation & Maintenance (2-yr period) (Section 02500)	1	LS		1	LS	
	ORC Injection						
8	ORC Injection (Section 02600)	1	LS		1	LS	
	COSTS						

NOTES:

1. **Submittals include: (Section 01400)**
   Contractor's Health and Safety Plan
   Foreign Object/Debris Management Plan
   Schedule Preparation
   Progress Meeting Minutes
   Work Plan for Monitoring and Injection Well Installation
   SVE System O&M Manual

2. **Meetings include: (Section 01200)**
   Pre-Construction Meetings
   Progress Meetings
   Final Inspection

3. Contractor may attach back-up detail as necessary with this bid form